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FISCAL YEAR 1989 DEPARTMENT OF ENERGY AUTHORIZATION

(Nuclear Energy R&D and Remedial Action and Waste Technology)

HEARINGS

BEFORE THE

SUBCOMMITTEE ON
ENERGY RESEARCH AND DEVELOPMENT

OF THE

COMMITTEE ON
SCIENCE, SPACE, AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

ONE HUNDREDTH CONGRESS

SECOND SESSION

MARCH 16, 17, 1988

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1989 DEPARTMENT OF ENERGY AUTHORIZATION

WEDNESDAY, MARCH 16, 1988

House of Representatives,
Committee on Science, Space, and Technology,
Subcommittee on Energy Research and Development,
Washington, DC.

The Subcommittee met, pursuant to notice, at 2 p.m., in room 2318, Rayburn House Office Building, Hon. Marilyn Lloyd [Chairman of the Subcommittee] presiding.

Mrs. Lloyd. The Subcommittee will come to order.

Good afternoon, ladies and gentlemen. Pursuant to House rules, I do ask unanimous consent that the Subcommittee permit today's proceedings to be recorded by the public, and hearing no objection, so ordered.

The hearing this afternoon will focus on the Department of Energy's proposed fiscal year 1989 budget for Nuclear Fission energy research and development. The DOE proposes five programs in this budget totaling $352 million in expenditures.

Now these activities include the development of liquid metal and high temperature gas reactors, the development of nuclear electric power systems for use in space, the operation and maintenance of facilities at our National Laboratories to support various fission R&D activities, the production and testing of isotope power systems for use in space; and finally, the improvement of light water reactors.

Funds for national nuclear energy research and development programs must be balanced among long-term societal needs, interim-needs, and short-term needs. The largest share going to long-term technologies, and the smallest going to short-term technologies.

The liquid metal technology is a long-term technology that promises to expand uranium reserves by many centuries, but is linked to the deployment time when reprocessing becomes economic.

It has appropriately been proposed for the lion's share of the DOE's nuclear budget when one includes the unique LMR support facilities. Now unfortunately the Department of Energy proposes spending a disproportionate amount of the available funding on near-term light water technology, and not enough on the intermediate high temperature gas reactor technology.

So in my view it is inappropriate to spend only $7 million on HTGR technology, especially since the Federal role should be to support longer-term higher risk activities.

My perception is that any domestic reactor orders that are forthcoming are likely to be for the next generation of machines that are modular as well as inherently safe, both in terms of public safety and financial investment.

Additionally, this next generation reactor must be cost-competitive, and be constructable in three to five years. Such a next generation reactor is the high temperature gas reactor, and this technology must command a larger share of the budget, but we will be hearing more about this as our hearings progress.

A large share of the proposed nuclear research budget is devoted to development of power sources for use in space. The Nation's and the world's most challenging frontier remains outer space and advanced power sources are critical to future civilian as well as defense missions.

The Subcommittee has strongly supported these activities and the funding for them, and I believe will continue to do so.

Our hard-working and distinguishing ranking Minority member is not here at this time.

[The prepared opening statement of Mr. Morrison follows:]

OPENING STATEMENT

HON. SID MORRISON

MARCH 16, 1988

Good afternoon. Today we begin our hearings on the Department of Energy's budget for Nuclear Fission R&D and related areas.

I am pleased to see the progress made in the Nuclear Energy R&D program over the last year, and the continued support of the DOE to maintain a budget level that is needed to meet long-term goals of this program. The focus on enhanced safety analysis and testing and standardization is particularly encouraging, because this would provide us with some good answers to those questions involving public attitude, economics, and licensing.

I want to commend the Department for the accomplishments in the space nuclear power program. It is important to establish a sound technical base for meeting the needs of future civilian and defense missions, and Mr. Dennis Bitz has done an excellent job in managing the programs to develop the technologies for the SP-100 and multimegawatt space reactors, radioisotope thermoelectric generators (RTGs), and the dynamic isotope powered system (DIPS). We do have a big challenge ahead of us. As I mentioned in the Space Nuclear Power Symposium at Albuquerque last January, a firm mission must be established for the SP-100 program. I believe the Department of Defense, NASA, and the DOE are now putting together these mission plans. The SP-100 technology can also make a significant contribution to NASA's new "pathfinder" project which is the first step in ensuring the United States' leadership in space.

In the Advanced Reactor R&D arena, I am pleased with the on-going activities for liquid metal reactor design and development, and the continuing effort to pursue private sector and international support for the design of the modular High Temperature Gas Reactor (HTGR). I want to hear about DOE's plan for the metal fuel cycle, particularly in the area of facility utilization, and the budget required to keep the test reactors running safely and effectively.

The Light Water Reactor program has a challenge to meet in the next 3 years when a standardized design can demonstrate the licensability by the Nuclear Regulatory Commission. I urge the Department to work closely with the utilities to define their needs for light water reactors in the future, because those needs are the driver for this program.

Again, it is a pleasure to be here today, and I am anxious to hear the testimony from the distinguished witnesses representing all facets of the nuclear energy arena.

Mrs. LLOYD. We are all stretched pretty thin, because all of us have two or three meetings going on at the same time. I'm sure you are very well aware of this. But we are looking forward to the testimony of Mr. Ted Garrish. This is his second consecutive hearing with us, and we are pleased to welcome you as our first witness today. I know you have other places to go as well today.

Mr. Garrish is the Assistant Secretary for Nuclear Energy in the Department of Energy. We welcome you, gentlemen, and you may proceed as you wish, and your entire statement will be made a part of the record.

STATEMENT OF HON. THEODORE J. GARRISH, ASSISTANT SECRETARY FOR NUCLEAR ENERGY, U.S. DEPARTMENT OF ENERGY, WASHINGTON, DC, ACCOMPANIED BY DR. DELBERT F. BUNCH, PRINCIPAL DEPUTY ASSISTANT SECRETARY

Mr. GARRISH. Thank you very much, Madam Chairman. This is my second appearance today before your distinguished Subcommittee. I am pleased to appear today to discuss the Department's program for support of its fiscal year 1989 budget request for Nuclear R&D and Remedial Action activities.

I am accompanied today by Del Bunch, my principal deputy, and other key program officials, who will assist me in responding to your questions as the need arises.

As you know, nuclear energy continues to play a critical role in maintaining a secure and stable energy supply. Without nuclear energy, an additional 7 million barrels per day would be required, 7 million barrels of oil per day.

This would have a significant impact on oil prices and upon our strategic dependence on imported oil. Nuclear power is important to assuring a balanced, diversified and secure energy supply for the country.

Mrs. LLOYD. Ted, would you excuse me? That is a recorded vote, and before you get started, I think it might be wise for me to make this vote and get back just as soon as possible.

[Recess.]

Mrs. LLOYD. The hearing will come to order.

Mr. Garrish, I am very sorry for the inconvenience. You may please continue.

Mr. GARRISH. To continue, I was saying that nuclear power is important to assuring a balanced and diversified and secure energy supply for America. Our budget is intended to support that goal. Eighteen percent of our electricity supply currently comes from nuclear power, and we will need new generating capacity in the mid-1990's to replace our old plants, and to meet these increasing demands, we will need nuclear power to meet that objective.

Utilities should be able to consider building nuclear power plants to meet the portion of this new capacity, yet the nuclear power option faces numerous interrelated institutional problems that makes its future use somewhat uncertain.

Nuclear power is at a critical point in its development, and a program is needed to address these institutional problems. And let me just discuss a few of those items that need to be addressed.

First is our high level nuclear waste program. We must put in place facilities as soon as possible to safely store nuclear waste and that problem needs to be solved.

Price-Anderson. We need to have Price-Anderson legislation reauthorized. It is extremely important for the future orders of nuclear plants, and that needs to be accomplished as soon as possible.

We need to improve the licensing process. As you know, last year we supported a bill in the past and submitted it to the Congress, and we are pleased this year with Mr. Moorhead's legislation dealing with this subject.

We need to improve plant designs through our reactor R&D. In our light water program, we are pursuing enhanced reactor designs and capabilities for light water reactors. We are in the process of working with the industry and the NRC to certify a standardized reactor design, a concept that will facilitate future licensing of such plants.

We also have a program to extend the life of reactors as another area where we are substantially involved, and we are performing research and analysis of the safety and performance of existing reactors to resolve the issues regarding possible life extension.

Looking further into the future, we are also exploring the concept of passive safety features in an effort to develop a future class of reactors with more inherent safety features.

The Advanced Reactor R&D—in that program, we are focusing efforts on developing an advanced reactor technology such as the liquid metal-cooled reactor and the high temperature gas reactor.

Those are important programs that our budget is intended to support. Recognizing the potential of other nuclear power technologies, we feel it is important to continue our progress in developing advanced power systems for space and other remote uses.

Finally, we believe we must continue the progress in the area of low-level waste disposal and remedial action, and the activities necessary to protect the environment and to assure the public health and safety. The States have made great progress on this program and it needs to be continued in the budget this year.

With respect to Remedial Action activities, we will continue our efforts to clean up contaminated facilities in the uranium mill tailing sites. In addition, we continue to work with Congress to extend the authorization of the Uranium Mill Tailings Remedial Action Program through the end of fiscal year 1994.

Generally those are the primary concerns our budget is intended to address, and with those opening remarks, if I could, I'd like to ask that my complete statement be included in the record.

Mrs. LLOYD. Without objection, your complete statement will appear in the record.

[The prepared statement of Mr. Garrish follows:]

STATEMENT OF THEODORE J. GARRISH
ASSISTANT SECRETARY FOR NUCLEAR ENERGY
U.S. DEPARTMENT OF ENERGY
BEFORE THE
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

MARCH 16, 1988

Madam Chairman. I am pleased to have this opportunity to discuss the Department of Energy's (DOE's) program and fiscal year 1988 budget request for its Nuclear Energy Research and Development (R&D) and Remedial Action and Waste Technology activities.

The requested funds are distributed among program elements as summarized in the following tables.

Program Element	Budget Authority ----($ in Millions)---- FY 1988 Appropriation	FY 1989 Request
Energy Supply R&D		
Nuclear Energy R&D	$ 347.0	$ 351.9
Remedial Action and Waste Technology	$ 246.8	$ 260.3
Policy and Management	$ 2.2	$ 2.1
TOTAL	$ 596.0	$ 614.3

Program Element	FY 1988 Appropriation	FY 1989 Request
	Budget Outlays ----($ in Millions)----	
Energy Supply R&D		
Nuclear Energy R&D	$ 342.2	$ 364.8
Remedial Action and Waste Technology	$ 262.8	$ 272.9
Policy and Management	$ 2.2	$ 2.2
TOTAL	$ 607.2	$ 639.9

Detailed funding tables are included in the discussion of each major program.

OVERVIEW

Nuclear energy plays a critical role in maintaining a secure and stable energy supply. Worldwide consumption of oil is about 59 million barrels of oil per day. Without nuclear energy, an additional 7 million barrels per day would be required to replace the electricity generated by using uranium as its fuel source. This would have a significant impact on oil prices and upon our strategic dependence on imported oil.

Nuclear power plays a key role in assuring a balanced, diversified, and secure energy supply for America. Over 100 commercial nuclear powerplants generate nearly 18 percent of the United States' electricity supply. Based on conservative projections, there will be a need for new electrical generating capacity by the mid-1990's to replace old plants and to meet the increased demands of our expanding population and economy. Utilities should be able to consider building nuclear plants to meet a portion of this new capacity, yet the nuclear power option faces numerous, interrelated institutional problems that make its future use in the U.S. uncertain.

Nuclear energy is at a critical point in its development. A national program is needed that will effectively address these institutional problems to ensure the continued development and deployment of nuclear power sources. Although nearly 400 nuclear plants have been constructed worldwide, we in the United States need to resolve those issues that challenge the future use of nuclear power as a key contributor to our country's energy security, stability, and strength.

First, we must put in place facilities that will safely store nuclear waste. Congress, through recent amendments to the Nuclear Waste Policy Act, has provided the framework within which the Department can proceed to select sites and construct facilities that can safely dispose of high-level radioactive waste. The Low-Level Radioactive Waste Policy Amendments Act of 1985 provides a fair and practical framework that will lead to new low-level waste disposal capacity developed by individual States and regions with limited Federal assistance.

Second, Congress must extend the Price-Anderson nuclear insurance and contractor indemnification system. Price-Anderson renewal is an affirmation of our joint commitment to the future of nuclear power. Without this mechanism to ensure that the public would be fully compensated for damages arising from a nuclear-related incident, no new nuclear plants will be ordered. Moreover, we will find it increasingly difficult to attract and retain qualified industrial partners to operate the Government's unique nuclear research and production facilities.

Third, domestic fuel cycle activities, including the uranium enrichment enterprise, must have an opportunity to compete in world markets as an essential part of assuring a secure domestic fuel supply.

Finally, the elimination of uncertainty in costs and schedules is an essential prerequisite to new nuclear plant orders. Revisions to State economic regulation and the process by which commercial nuclear facilities are licensed must be made if we are to have nuclear power available to meet a portion of a needed expansion of our generating capacity.

We believe that the DOE programs provide an important contribution toward resolving these institutional issues and provide for the long-term development and deployment of nuclear power sources. The goals of these DOE programs are:

o to complement industry-led efforts to secure nuclear power as an attractive option for new electricity capacity in the 1990's.

o to conduct R&D on advanced reactor systems that show the potential for significant breakthroughs in economics, safety, or waste management.

o to utilize nuclear technology to meet NASA and DOD power requirements to enable future civilian and defense-related missions.

o to fulfill our commitment to our environment by conducting appropriate remedial action activities.

o to ensure a U.S. uranium enrichment capability that can meet domestic requirements and support important ties with foreign utilities.

More detailed discussion of these factors and the scope, status, and budget request for all programs is contained in the sections that follow.

NUCLEAR ENERGY RESEARCH AND DEVELOPMENT

The funding request for nuclear energy R&D programs is contained in the following table.

Program Element	Budget Authority ----(S in Millions)---- FY 1988 Appropriation	FY 1989 Request
Nuclear Energy R&D		
Light Water Reactors	S 32.0	S 26.8
Advanced Reactor R&D	92.6	61.2
Space/Defense Power Systems	75.2	117.0
Advanced Nuclear Systems	21.0	27.7
Facilities	117.7	110.7
Program Direction	8.5	8.5
Total	S 347.0	S 351.9

LIGHT WATER REACTORS

The Nation's economic and national security requires a diversified energy supply base built upon adequate. domestic resources that are relatively free from international pressures. Nuclear energy is a vital component of the national energy supply and is essential to meet current and future national energy demands.

The Light Water Reactors (LWRs) program is one component of the Civilian Reactor Development Program. The mission of the Civilian Reactor Development Program is to support the national energy supply policy by developing and implementing programs to ensure that nuclear energy remains a safe, economically competitive and environmentally acceptable option that continues to contribute to national energy stability, security and strength.

The fundamental goals that must be achieved to fulfill the mission of the civilian reactor development program are:

- to provide an effective and predictable regulatory and institutional environment that enables nuclear power projects to compete freely in the marketplace:
- to support and facilitate industry-led technology efforts to revitalize the LWR option for the U.S. and to ensure its long-term availability as a vital component of the national energy supply system:
- to explore the feasibility and practicability of advanced nuclear reactor systems with the potential for breakthroughs in economics. safety, licensability, and waste management options: and.
- to support long-term national interests by conducting cooperative international nuclear R&D projects that further U.S. nonproliferation objectives strengthening our position in international commerce. involving key universities in nuclear R&D utilizing DOE facilities and providing options to meet longer-term needs to extend uranium resources.

The last two goals are addressed by the Advanced Reactor R&D Program which is discussed in a later section.

The LWR program is focused primarily on the first two goals. It provides visible national support and complementary research and development to foster successful industry-led efforts to ensure the availability of the LWR option.

The objectives of the LWR program are to:

- encourage development of improved designs and support Nuclear Regulatory Commission (NRC) and utility certification of such designs for use as standardized plants for the 1990's;
- utilize the results from severe accident, source term, and safety technology programs to assist in the removal of institutional barriers currently inhibiting the introduction of advanced LWR's in the U.S. marketplace:
- support industry initiatives through complementary R&D to extend the life of the Nation's existing nuclear powerplants; and,
- provide technical support and analyses of domestic and foreign efforts to improve the opportunities for the LWR option.

Success in advancing the LWR option is essential to meet projected power demands of the 1990s.

The major focus of the program is to develop and obtain utility and NRC certification of a much more attractive version of LWR technology, the Advanced Light Water Reactor (ALWR), suitable for deployment in the years ahead. This first program element augments industry reactor design programs and is oriented towards designs which can be deployed without the need for a demonstration plant. It includes support for certification, by the NRC, of an advanced 1,300 megawatt-class pressurized water reactor (PWR) and an advanced boiling water reactor (BWR) by 1991; development and key features proof testing of innovative mid-sized (600 megawatts of electric power, or MWe) BWR and PWR plant concepts; and supporting activities to ensure that plants are designed for constructibility, and later incorporation of advances in the technology. These activities fulfill the Department's commitments to complement the Electric Power Research Institute (EPRI)/industry work on advanced LWR's.

The second program element--Current and Advanced Light Water Reactor Safety and Licensing Support--provides technology support to the ALWR program. It applies the results of the severe accident technology programs to the implementation of the Severe Accident Policy Statement for ALWRs to prevent severe accident issues from forestalling acceptance of ALWRs. It develops technology to support the extension of nuclear powerplant life beyond the current 40-year licensing period. and provides the basis for achieving the ALWR design life of 60 years. It further explores solutions to other institutional impediments to the deployment of nuclear powerplants.

Advanced Light Water Reactor Program

U.S. utilities have. for several years. been leading an industry-wide effort to establish a technical foundation for the design of the next generation of light water reactors in the United States. This utility initiative has been effected via a major technical program managed by EPRI. The Department's ALWR Program is closely coordinated with the extensive related advanced light water reactor work sponsored by EPRI. The program is growing in national and international prominence and it now involves participation on the part of several Far East utility companies. with prospects of one or more European partners as well.

This ALWR Program has been established to meet the need in the U.S. for a new generation of light water reactor plants. Despite the political and institutional factors which today discourage the continued deployment of nuclear power sources in the U.S., nuclear energy remains an important part of our nation's present and future power supply.

Three fundamental standards must be met before the ALWR can be considered a viable candidate for U.S. utility investment. First, it must be an excellent powerplant in all respects. This includes safety, foremost. but must also embrace all of the criteria by which real powerplants are measured. including reliability. maintainability, and compatibility with the environment. Secondly. it must be economically attractive in comparison to its alternative fossil-fired units. Finally, and of particular importance for nuclear plants. the ALWR must provide very high protection of utility investment. in terms of predictable construction costs and schedule. assured licensability. predictable operating and maintenance costs. and very low risk of severe accident. In short. the investor must have extremely high confidence that the high capital cost of a nuclear plant is warranted.

The Department's ALWR program includes three key tasks:

- support for the EPRI/industry program of defining technical requirements for ALWRs;
- support for certification of two ALWR standard plant designs to demonstrate resolution of technical issues and the efficacy of the standard plant licensing process: and,
- performance of a technology program to develop greatly simplified mid-sized (about 600 MWe) LWRs that apply predominantly passive safety

features, and assuming favorable results, to support licensing of such standard plant designs.

The first task involves support for industry generation of detailed requirements for future LWRs. There are over 100 operating nuclear plants in the United States. These plants constitute an extraordinary experience base from which compelling conclusions can be drawn regarding both desirable and undesirable design features. Notwithstanding plant-to-plant variations. the overall performance of U.S. nuclear plants has been good. Specific regulatory guidelines. plant operator training methods. and specific hardware designs have evolved based on these existing reactor systems. For all these reasons. a logical and high-success approach for the ALWR Program is to examine carefully this existing technical basis and to develop an ALWR design which is an evolutionary improvement or refinement of the existing design base. Industry appropriately has the lead in this effort.

EPRI's efforts pursue this course in developing a set of specific and detailed design requirements for an evolutionary ALWR, for both BWR and PWR designs. In each case the design concepts, systems. and hardware specified are conventional in nature, but they employ the ALWR principles outlined above. For example. a PWR designed to the standards established for the evolutionary ALWR would utilize a conventionally configured reactor coolant system, but with substantially improved reactor coolant pump seal design, steam generators having greater secondary side-water inventory. and a pressurizer designed to accommodate a full post-scram pressure and temperature transient without requiring pilot-operated relief valve actuation. The BWR version of the evolutionary ALWR would employ internal recirculation pumps and improved control rod drive design.

The second task of the Department's ALWR program includes support for safety reviews by the NRC of two large (1,250 to 1,350 electrical megawatts, or MWe) standard plant designs--the General Electric (GE) Advanced Boiling Water Reactor (ABWR) design, developed in collaboration with the Japanese. and the Combustion Engineering (CE) "System 80+" Advanced Pressurized Water Reactor (APWR) design, using the "System 80" Palo Verde design as its basis. Good progress was made last year in establishing the NRC review process. coordinating with the EPRI/utility industry requirements and criteria. and in submitting the initial chapters of the Standard Safety Analysis Reports (SSARs) to the NRC for review. These SSAR submittals. and related safety analyses. will continue throughout FY 1988. In FY 1989. additional required risk assessments and safety evaluations will be prepared. and revisions to the safety reports and evaluations as needed to resolve NRC comments will be submitted. Based on favorable review. these plant designs are expected to be certified by the NRC in late 1991.

In the third task area. technology development support is being provided for two mid-size (600 MWe) plant concepts--a BWR and a PWR design. These plants offer the opportunity to incorporate further, highly desirable. evolutionary changes to LWRs. Designs are being developed which will not only build on the extensive experience base from the last three decades of reactor operation. but will also take advantage of potential simplifications and innovations in design and construction that are unique to the smaller power rating. These include the application of more-passive systems and the increased use of modularization to improve construction.

The passive LWR design option is less developed but very attractive over the long term. In concept, the ALWR passive plant is one which employs primarily passive means (such as gravity or natural circulation) to remove decay heat and provide emergency core cooling to prevent core damage, as well as to contain fission product activity even in the unlikely event of a core damaging accident.

The incentives for developing a passive plant concept are substantial:

- The passive plant protection systems envisioned are vastly simpler in concept than the complex safety systems utilized in existing plants. Therefore, the passive plant offers far greater opportunity than the evolutionary plant to effect wholesale simplification (in the form of reduction of many valves, pumps, takes, instruments, etc.) with attendant improvement in construction cost and schedule, plant operability, and maintainability.
- By eliminating reliance on active components and human intervention, the passive plant has potential to offer greater safety under a wider range of upset conditions and internal and external plant threats such as loss of all electrical power.
- The passive plant may be more easily licensable than existing plants because of the substantially reduced space of safety related equipment.
- The passive plant offers potential for renewed public and governmental confidence in that it represents a significant improvement over current practice.

A plant size of about 600 MWe may prove to be an advantage in its own right since it may fit more easily into the capacity planning schemes of most U.S. utilities. Also, such plant sizes offer a potential for shorter construction time, more extensive modularization of plant equipment, and other factors that can improve overall plant economics.

Safety and Licensing Support of Current and Advanced LWR'S

The three elements of this part of the program dealing with plant lifetime, severe accidents, and institutional matters support not only ALWRs but also bear significantly on extension and preservation of the current national energy resource represented by today's LWRs.

The 100-plus nuclear powerplants now in commercial operation are a large, untapped resource of energy when one considers that their current license life of 40 years is not based on technical restrictions. An additional 20 years of operating life, representing nearly 88,000 megawatts of capacity, is potentially available and can directly offset some of the need for new or replacement generating units. In order to preserve this resource, the criteria and technical bases for replacement, refurbishment, or continued use of components and systems, are needed by both utilities and regulators. In addition, the procedural requirements to be used by regulators for license extension reviews must be developed and agreed upon. This ranges from questions on compliance with regulations issued during the plant operating life to issues on cost recovery allowances by economic regulators. In FY 1988, the development of the technical base for one of the key components, the reactor containment, will be pursued. Questions regarding electrical cable and reactor vessel life are also being addressed. In FY 1989, support for a lead plant, including safety analyses and application of developed criteria, will be initiated with a selected utility contractor on a cost-shared basis for preparation of the initial application for license renewal. This is a key step toward the final objective of getting the lead plant license renewal in 1993.

In the severe accident area, one aspect of the program is to apply expertise gained from the severe accident technology program to the identification of potential design improvements for future plants that may result from the resolution of severe accident issues. In cooperation with the utility ALWR Steering Committee, the DOE program has provided input on safety requirements and supporting bases for a Utility Requirements Document. The key chapter on safety and severe accidents in this document has been submitted to NRC and interactions with NRC will take place during FY 1988. In FY 1989. discussions with the NRC on the acceptability of these requirements will be completed. As part of the support the severe accident program is providing to the ALWR certification program, topics papers on key severe accident issues are being prepared. These papers represent suggestions for closing severe accident issues for the ALWR. Two sets have already been provided to the NRC by CE officials and the additional four topic sets will be provided in FY 1988. Interactions with the NRC staff on these severe accident issues, initiated in FY 1988, should be completed during FY 1989. Documentation of these results will be incorporated in specific Final Design Approvals from the NRC for the ALWR designs, as well as in revised NRC rules, regulations, and guides. A multiple benefit of this issue resolution process will be the application of the conclusions to current operating plants.

Another aspect of severe accident investigations deals with understanding reactor concepts from other countries. The impact of an accident like Chernobyl makes it clear that we must understand the behavior--both strengths and vulnerabilities--of such designs and to coordinate feedback from these investigations into the design process in all countries.

In FY 1987, the loss-of-fluid test (LOFT) reactor was deactivated as the Organization for Economic and Cooperative Development (OECD) LOFT consortium proceeded with preparations to perform a post-test irradiation examination of the damaged test fuel. These examinations will be completed in FY 1989.

Three Mile Island

No additional funding for Three Mile Island (TMI) activities is being requested in FY 1989 because DOE will complete its R&D program with funds appropriated for FY 1988.

The GPU Nuclear Corporation (GPU Nuclear) expects to complete defueling of the core debris by the end of 1988 and complete shipment of the core debris in 1989. GPU Nuclear also expects to complete the recovery program and place the plant in a safe, monitored condition during 1989.

Shipment of the core debris is a joint effort shared by GPU Nuclear and DOE. Currently, GPU Nuclear tasks for debris removal and loading into canisters control the schedule. DOE will maintain shipping on a schedule consistent with fuel availability. Approximately one-half of the

300,000 pounds of core debris material had been shipped to the Department's Idaho National Engineering Laboratory (INEL) by the end of 1987.

The TMI Unit 2 Accident Evaluation Program made progress in the areas of sample examination and accident evaluation during FY 1987. The program issued a revised accident scenario that incorporated observations from core bores that penetrated through the rubble to the bottom of the core. In some cases, the bore tool extended into the lower plenum within 10 inches of the bottom head. Additional information on fission product distribution and more detail on the condition of the lower core has been obtained as debris is removed and the lower regions of the vessel are exposed to allow direct examination. A large number of samples of core debris were shipped to participating OECD/Committee for the Safety of Nuclear Installations (CSNI) members for extensive examinations. These results will be coordinated and integrated with the examinations being carried out by the Department and the NRC. During FY 1988, a final revised accident scenario incorporating the results from the CSNI program will be prepared. This will include the observations made during the lower vessel defueling and DOE sample examinations.

ADVANCED REACTOR R&D

For FY 1989, the Department is requesting $171.9 million for advanced reactor research and development and nuclear energy facilities support. Advanced nuclear reactor power systems offer the potential for significant breakthroughs in economics, safety, licensability, and waste management options compared to LWR systems. The principal vehicle for achieving these breakthroughs is the Integral Fast Reactor (IFR) concept, which uses a metal-fueled, liquid metal-cooled system.

The goal of the Department's Advanced Reactor R&D program is to develop and demonstrate liquid metal-cooled reactor (LMR) and high-temperature gas-cooled reactor (HTGR) systems that meet evolving market needs. The introduction into the marketplace of new reactor systems developed through R&D on advanced technology depends on the attractiveness of the technology to utilities and the public and on the need for additional generating capacity. It is important to verify that these alternative systems do, in fact, provide the promised breakthroughs; that modular plants can overcome the economies of scale enjoyed by large plants; and that these designs are at least as, if not more, licensable than competing LWR designs. Current licensing reviews are of paramount importance in pursuing these objectives. The program is organized into two major areas--first, LMR design, fuel cycle, and technology R&D (which are supported by essential test facilities) and, second, modular HTGR design and technology R&D.

Significant breakthroughs in economics, safety, licensing and waste management options are important objectives of the Department's program. The Department believes that these objectives can be achieved through new reactor designs and exploration of advanced fuel cycle options. The promise that these new systems hold is clear--modular, standardized designs will lead to lower costs; factory fabrication will lead to stabilized lower construction costs and improved quality assurance; the capability of increasing capacity by combining standard modules will meet utility load growth and financial constraints; advanced control systems will lead to improved reliability and operator response; and the use of passive safety systems will assure the termination of the chain reaction process and the return of the reactor to a safe, stable state under a wide-range of plant conditions. The intent of the design development activity, including NRC and utility reviews, is to determine whether inherent safety features and opportunities for shop fabrication of both LMR and HTGR systems will lead to an attractive product as compared to future LWRs and coal plants.

Advanced Liquid Metal Reactor

The Department is giving priority support to the development of the IFR concept based upon R&D work completed to date that shows the potential for significant breakthroughs in improved economics, passive safety, licensability and waste management options. This metal-fueled, liquid metal-cooled system has the additional potential for spin-off applications for defense missions and as an actinide burner which could greatly simplify nuclear waste management.

Specifically, the Department will focus metal fuel development R&D in FY 1989 on safety tests in support of key design and licensing requirements, fuel fabrication and testing to demonstrate performance and full scale fabrication capability, and demonstrating the metal fuel cycle including reprocessing and an advanced waste treatment process.

While ternary metal fuel is the current reference design, efforts on the LMR oxide fuel cycle will continue in FY 1989 as part of a cooperative R&D effort with the Japanese. In support of this program, in FY 1989 the Department will continue the Core Demonstration Experiment with a large-scale test of irradiated mixed-oxide fuel with planned completion in 1992 and complete PFR/TREAT tests in cooperation with the United Kingdom. The collaborative reprocessing program with Japan will continue; key elements of this collaborative effort include disassembly system design, dissolver design, and related activities. Technology development verifies design features, safety margins, and potential cost savings of advanced reactor systems. Performance expectations will need to be confirmed for new plant features, control systems, components, and materials.

Modular High Temperature Gas Reactor

The FY 1989 budget request includes $7.7 million for modular HTGR development. In FY 1989, the Department's efforts will focus on maintaining a base technology to support future applications of the HTGR and to allow continued collaboration with international programs where advanced designs and supporting R&D are being actively pursued. Preliminary design activities initiated in the United States in FY 1988--along with continuation of existing international agreements with Japan, the Federal Republic of Germany (FRG), France, and Switzerland--will provide a basis for this U.S. collaboration.

FACILITIES

DOE's test facilities are among the most advanced and sophisticated in the world and are essential to the continued development of advanced reactors, fuels, components, and materials. The major facilities involved in the Department's advanced reactor R&D efforts are located at three sites: Argonne National Laboratory-West (ANL-W) in Idaho; the Energy Technology Engineering Center (ETEC) in California; and the Westinghouse Hanford Company (WHC) in Washington. Funding for the operation and maintenance of these facilities has been reduced substantially in recent years. Over the last 7 years the facilities program budget has been reduced by approximately 50 percent, due in part to improved operational efficiency and in part to completion of construction work in progress. Any facilities that do not directly support reactor development programs have been shut down or converted to other uses.

Although DOE has been successful in reducing its funding requirements for facilities, safety and quality of operation continue to be of the highest priority. The FY 1989 budget request provides for the continued safe and effective operation of its nuclear test facilities.

To reduce further the funding requirements of operating these facilities, a privately financed, cogeneration system or "Power-Pak" addition is nearing completion at ETEC and is planned to begin operation in FY 1988. The addition of this cogeneration system will provide revenues from electricity sales which will partially offset operating costs and provide low-cost steam generator performance and endurance testing.

ETEC focuses on non-nuclear testing of liquid metal components with an emphasis on steam generator performance and endurance testing, which is conducted at the Sodium Component Test Installation. In FY 1989, initial performance testing of the 70 thermal megawatt (MWt) helical coil steam generator will be conducted utilizing the "Power Pak" electrical-generation revenue to significantly offset test costs. LMR design verification testing and testing in support of the SP-100 program will also be conducted at other ETEC facilities. Also in FY 1989, under a cooperative program with the Japan Atomic Power Company, the facility modifications required for the future testing of the DOE double-walled tube steam generator and for a Japanese test model will be initiated.

The ANL-W site is the technology center for the metal fuel development program and for reactor operations and metal fuel reprocessing, fabrication, and waste treatment demonstrations to verify the closed metal fuel cycle. At the ANL-W Experimental Breeder Reactor-II (EBR-II) and Transient Reactor Test (TREAT) facilities, test programs such as waste management, fuel performance, failed-fuel testing, passive reactor safety testing, and criticality experiments are being conducted. During FY 1989, the conversion of the EBR-II core to a composite of binary and ternary alloy metal driver fuel will be completed, automated control strategies fully compatible with passively safe plant response to upsets will be demonstrated, and transient overpower tests of passive safety and the operational transient program will be conducted. Modifications will continue on the ANL-W Hot Fuels Examination Facility (South) for metal fuel refabrication, reprocessing and waste treatment technology development and verification, and qualification and acceptance testing of systems will be initiated. After completion in FY 1988 of the SP-100 final core design tests, the Zero Power Physics Reactor (ZPPR) at the ANL-W site will be maintained in a standby condition, except when a program test sponsor provides funds to cover operating costs.

As a part of meeting our commitment to support key universities to conduct nuclear R&D, DOE has formulated an opportunity for Argonne to serve as a catalyst in implementing significant college and university multidisciplinary research around the EBR-II and the IFR concept. Faculty and students at U.S. colleges and universities will be provided an opportunity to participate in "hands-on" experience across the broad spectrum of nuclear engineering--an element that utilities and other prospective employers of engineers consider to be vital.

The FFTF serves as a national multipurpose facility. Test programs required for space and defense programs, fusion, isotope production, and international programs are being conducted. Activities to be conducted in FY 1989 include tests for the space and defense energy program, including irradiation of a prototypical SP-100 fuel test article, fuel and blanket tests under a cooperative DOE/Japanese agreement, tests for the fusion program, and the initiation of a long-range upgrade program for selected FFTF reactor systems equipment. In FY 1989, FFTF operations with binary metal driver fuel will be initiated, and the complete irradiation of the first prototypical ternary (U-Pu-Zr) metal fuels test assembly will be completed.

In addition to these facilities, the Integrated Equipment Test (IET) facility at the Oak Ridge National Laboratory (ORNL) provides unique capabilities for developing and demonstrating remotely operated and maintained equipment and systems. These are mainly used in support of oxide reprocessing, but are also applicable to other hazardous operations and environments, such as reactor maintenance and operations in space. The IET is being utilized to conduct a major multi-year oxide reprocessing exchange agreement with Japan-PNC and to carry out other international technology exchange agreements in the fuel cycle area with the United Kingdom, France, and the FRG.

SPACE AND DEFENSE POWER SYSTEMS

The Space and Defense Power Systems program is an important element of the Department's Nuclear Energy R&D effort. The program's primary mission is to develop nuclear energy systems to respond to requirements identified by the National Aeronautics and Space Administration (NASA) and the Department of Defense (DOD), including the Strategic Defense Initiative Organization (SDIO). Program activities include the design, development, and technology support for building and testing compact, high performance reactors for space and terrestrial applications and dynamic isotope power systems for space application. In general, these power systems and the technologies developed in this program are intended to operate in remote and demanding environments, independent from logistical supply chains. In many cases, they represent the only power sources capable of fully meeting user mission requirements. Currently, the emphasis is on space power systems. The program comprises three firm projects--the Dynamic Isotope Power System (DIPS) in the range of one to ten kilowatts of electric power (kWe); the SP-100 Space Reactor in the range of tens to hundreds of kWe; and the Multimegawatt (MMW) Space Nuclear Power Program which covers the range from several to hundreds of megawatts of electric power.

The Department has undertaken these nuclear energy projects to meet expanding space and defense requirements as part of its overall nuclear development charter under the Atomic Energy Act to support other Federal agencies as well as civilian energy needs. In each case where DOE is proposing funding, it is as part of a joint project, cooperatively funded by DOD and/or NASA. Our space reactor projects build on the technologies developed as part of our civilian power reactor programs, primarily the liquid metal and gas-cooled reactor programs. It is anticipated that eventually there will be meaningful feedback to the commercial reactor programs from accomplishments of the space power programs, particularly in the areas of fuels and materials, and reactor control.

For FY 1989 the DIPS program increases from $6.3 to $21 million as a result of increased design, fabrication and testing activities under a recently awarded systems integration contract. The increase also provides resources to support modifications to facilities at the Hanford site near Richland.

Washington. These modifications are necessary to conduct future DIPS fuel module assembly and testing and to continue base radioisotope power generator projects. The DOD is considering this power source for use on the Boost Surveillance and Tracking System (BSTS) as well as on other missions. Similarly, the MMW program shows an approximately $10 million increase primarily to support detailed conceptual design studies being performed by industrial contractors. The SP-100 program funding remains essentially constant as a result of increased NASA participation and interest as a funding partner over the remainder of the program.

The combined funding request for DOE's Space and Defense Power Systems program increases from $75.3 million in FY 1988 to $117 million in FY 1989. This funding request includes a $15 million "fair share" irradiation and test charge for use of DOE test facilities. The key point regarding the funding levels for the Space and Defense Power Systems program is timing. For example, if the SP-100 reactor system is to be available and proven by the mid-1990's as desired by DOD, and if we are to be in a position to select one multimegawatt space reactor concept by 1992, then certain activities must be conducted now. The funding we have requested in FY 1989 is the amount needed to conduct all of these activities and to maintain a schedule commensurate with DOD's needs. Lower funding levels will simply not permit the availability of the various power sources by the desired need dates with the necessary confidence in the technology.

SP-100 Space Reactor Project

The triagency SP-100 program, begun in February 1983, will continue in its Technology Readiness phase during FY 1989. In 1985, the first phase of the project was successfully completed with the selection by DOD, DOE and NASA of a reactor concept utilizing thermoelectric energy conversion for development and testing and the selection of the preferred site for conducting a ground reactor demonstration test.

In late 1986, the system development contractor team, led by the General Electric Company, was selected and the SP-100 Ground Engineering System (GES) Program moved rapidly to integrate system developer activities with the previously established project team.

Early in 1987 the SP-100 Steering Committee (comprising DOD, DOE and NASA representatives) reduced the reference design power level from 300 to 100 electrical kilowatts. This decision was driven by user assessments of power level requirements associated with early missions compatible with the SP-100 power system. With funding shortfalls identified at the time of this decision, it also became necessary to extend the program an additional year. The required reprogramming was completed satisfactorily and, although the reference test power level was reduced to 100 kWe, the ability to use SP-100 technology from a few tens to hundreds of electrical kilowatts has been maintained.

Furthermore, FY 1988 funding levels for both DOE and SDIO have forced an additional restructuring of the program. These changes were partially offset by increased NASA participation in the SP-100 GES Program. The commitment by NASA for FY 1988 funding and for substantially increased funding in FY 1989 through FY 1992 allows the SP-100 GES Program to maintain a sufficiently broad and balanced approach to develop and validate space reactor technology on a schedule which is still compatible with projected user needs. but the replanning has eliminated any contingency in meeting the FY 1992 target. Any substantial future funding shortfall will require additional replanning of the program and would likely impact the ability of the program to meet cost and schedule goals.

Completion of a concerted design effort in August 1987 resulted in innovative design features to protect the core from a loss of coolant accident and to reduce system mass. The 100 kWe system design activities are proceeding as planned. both for the Generic Flight System and for the facilities and equipment needed to perform the ground testing of the reactor at WHC. In addition. substantial progress has been made by all project participants in implementing requirements for quality. reliability and safety programs.

In FY 1988. major accomplishments will include the final Generic Flight System design that will form the basis for the ground testing of components and assemblies to validate the performance and lifetime of the SP-100 power system. Component hardware will be designed and tested, and fuel for the reactor at the ground test site will be fabricated. The definitive design of the site facility modifications will also proceed. with major procurements of equipment occurring in FY 1989. Safety analyses will be performed to support the planned reactor tests.

Because of the recent replanning efforts, some activities initially planned for 1988 completion will continue into FY 1989. Major accomplishments in FY 1989 will include completion of the reactor test site definitive design and Preliminary Safety Analysis Report (PSAR), initiation of the fabrication of the vacuum vessel and modification of the existing reactor containment facility in which the GES test will be conducted. Key technology development activities will continue at the supporting national laboratories. In particular, most of the fuel production for the GES reactor test will be completed. Fuel and material testing and post-irradiation examination will continue at EBR-II and the FFTF. The system contractor will continue with the design, analysis, development, and testing of system components. Design of the major reactor ground test--commonly referred to as the Nuclear Assembly Test--will be completed and test article fabrication will commence. In preparation for a flight decision, planning with the user and system contractor is expected to be initiated, and the systems contract will be appropriately modified to permit the flight option to proceed at the outset of FY 1990.

Multimegawatt Space Nuclear Power Program

In 1985, the Multimegawatt Space Nuclear Power Program was established as a joint DOD/DOE program to meet power needs beyond those satisfied by the SP-100, in the range of a few MWe to hundreds of MWe. The program contains three elements--the MMW Space Reactor Program, the Thermionic Fuel Element Verification Program (TFE), and Centaurus.

The primary goal of the MMW Space Reactor Program is to identify at least one space nuclear power system concept by 1992 that meets the high performance, multimegawatt power requirements of advanced Strategic Defense Initiative (SDI) applications, and to resolve all feasibility issues by that time.

The MMW program is geared to push reactor, power conversion, and storage and heat rejection technologies well beyond that to be achieved in the SP-100 program. In a phased approach, the program is targeted to reach the stage of concept selection in FY 1992, similar to the status of SP-100 in FY 1985.

In March 1987, DOE completed scoping work on the definition of MMW reactor systems concepts and requirements, and incorporated the results into a Request for Proposals for five to eight preliminary system concept studies. These studies will include analyses, tradeoff comparisons, identification of technology feasibility issues, conceptual design configurations, and development plans for MMW space reactor power supplies. The six contractors selected in late January 1988 will perform system studies over a 10-month period beginning in mid-FY 1988. We expect to select two or three concepts for further development by mid-FY 1989. Concurrent with the contractor studies, supporting technology development activities will be performed at national laboratories. Potential technology efforts include the production of zirconium-coated uranium carbide fuel particles and particle bed fuel elements for FY 1988 fuel tests: demonstration of fabrication processes for uranium carbide fuel cermets; testing of properties and fabricability of high-temperature refractory alloys; and development of energy storage technologies.

Other activities planned in FY 1989 and beyond include the completion of a preliminary safety assessment for the selected concepts, resolution of feasibility items identified in the initial detailed system concept evaluations and tradeoff studies, detailed design configuration and specific component selections, and a further development plan and ground engineering system test configuration. The technology development program which focuses on and directly supports the selected two or three concepts will be pursued by industrial contractors with national laboratory support. Emphasis is expected to be placed on fuels and materials and on heat rejection. Upon completion of the second phase in 1992, at least one concept which meets the MMW program goals will be identified for possible selection by the SDIO to proceed with further development and testing during the mid-to-late 1990's and early next century, respectively.

Also included in the jointly funded MMW program are the TFE verification and Centaurus programs. The purpose of the TFE verification program is to provide sufficient irradiation performance data on thermionic fuel elements to allow their further consideration for MMW and other space power applications. In FY 1988 accelerated irradiation tests are being conducted in FFTF with similar tests planned in both the FFTF and EBR-II in FY 1989.

Based on test results and modeling input, design and fabrication of a prototype TFE assembly will be initiated in FY 1989 for subsequent real time irradiation in the FFTF.

The Centaurus program is targeted to complete the current phase of tests by the end of FY 1990. To that end, a test is planned for the TREAT reactor in FY 1988 and the design of another test is planned by FY 1989. Advanced concepts continue to be explored and benchmark reactivity and mockup flow tests are planned for FY 1989.

Irradiation and Test Charges

This program activity is to account appropriately for the increasing use of the Department's test facilities by the Space and Defense Power Systems Program. The proposed $15 million for FY 1989 represents the approximate proportional usage by the Space and Defense Power Systems Program relative to total facility use. Each program user still pays its incremental test costs, such as for test capsules and safety analyses. The high burnup fuel and material tests are essential to the success of the Space and Defense Power Systems Program.

Dynamic Isotope Power System

The needs of military spacecraft in the planning process include higher power requirements and increased survivability to threats directed at disablement or destruction of the space system. The current standard spacecraft power source, large and potentially vulnerable arrays of photovoltaic cells. may not meet all future military spacecraft survivability requirements. One class of spacecraft of current interest for high priority missions projected for the 1990s requires electrical power in the range of 1 to 10 electrical kilowatts, stringent attitude control and station keeping, and survivability from various threats.

The Dynamic Isotope Power System--an isotope-fueled power subsystem with a combined turbine-alternator--is an enabling technology for those military space missions that require survivability against various threats, higher power. and a small power supply to improve the fields of view of the sensors and the overall spacecraft pointing accuracy. This joint DOE/DOD demonstration project was initiated in FY 1986 under a supplemental agreement between the two departments. This agreement set up a cost-sharing arrangement. with DOD providing about two-thirds of the funds.

The primary objective of the DIPS project is to select. develop and demonstrate the necessary hardware required to provide a dynamic-conversion. space electrical power system in the range of 1 to 10 kilowatts output for use by emerging military and civilian space missions in the early 1990's and beyond. The DIPS project is focused on meeting the power needs of the BSTS system.

The DIPS project will demonstrate that all key technological issues have been addressed successfully through the design. fabrication, and testing of electrically heated Engineering and Qualification units. The Department has selected Rockwell International as the lead contractor to design and build a DIPS Engineering Unit and a DIPS Qualification Unit for ground testing. The major DIPS project goals during FY 1988 are the completion of the contract negotiation and the provision of support to the Air Force in system tradeoffs for the Boost Surveillance and Tracking System.

In FY 1988, the DIPS contractor is initiating a review and assessment of the Brayton and Organic Rankine conversion cycles, identifying critical components and beginning their testing, and initiating systems conceptual design studies. The procurement and manufacture of long-lead heat source materials are being implemented in FY 1988 in order to support a safety test program in FY 1989.

Conceptual design studies of the heat source/heat exchanger for both the Brayton and Organic Rankine cycles will be pursued by a DOE technical support contractor. in conjunction with DOE laboratories. to support the DIPS lead contractor. Brayton/Organic Rankine conversion cycle technology assessments and system conceptual design studies will be completed and a cycle/design concept will be selected by DOE with DOD concurrence. Additional FY 1988 work includes initiation of the DIPS Engineering Unit Design.

In FY 1989. the DIPS Engineering Unit Critical Design Review will be completed and the proposed design approved by DOE. The procurement of long-lead items and materials for the DIPS Engineering Unit manufacture will be initiated. and fabrication of the Engineering Unit will begin. Reliability. survivability and safety studies will be conducted in parallel with the Engineering Unit design activities and will complement these design activities. A System Safety Program Plan will be developed by the DIPS contractor and approved by DOE. Critical component development, performance, and life testing will be continued.

A new construction project is planned to be initiated in FY 1989 to modify an existing DOE facility to provide fuel production capability for both the DIPS and radioisotope thermoelectric generator (RTG) projects.

Pending a selection of DIPS by DOD to power BSTS and the approval of Supplemental Agreement No. 2 to the DOE/DOD Interagency Agreement, a DIPS Flight hardware project would be implemented so that DIPS flight units would be available on the BSTS schedule. DOE expects to execute this second supplemental agreement later this year.

Advanced Nuclear Systems

The Advanced Nuclear Systems (ANS) program develops, demonstrates, and delivers radioisotope power sources for U.S. military and civilian space and terrestrial missions. Included in the program are the base level support for fuel production and testing, nuclear safety analysis and testing, quality assurance, reliability and operational safety for DOD/SDIO/NASA missions that use, or will use, isotope power systems. DOE plans to continue to maintain a viable heat source production capability within its laboratory structure in order to support future RTG deliveries. This laboratory structure provides a national capability to support DIPS.

special applications RTGs, and future NASA missions. In 1988, DOE is maintaining and upgrading heat source production and RTG fueling capabilities.

Current programs supported under the ANS decision unit include the NASA Galileo and Ulysses missions, DOD Special Terrestrial Applications, and flight systems support to the DIPS program for Air Force and SDI applications. All of these projects are jointly funded with DOD or civilian agencies. Future missions on which isotope power systems are planned for use are Mariner Mark II (a series of NASA interplanetary missions in the early 1990's) and a DOD Special Terrestrial Applications project in the mid-1990's.

A major effort during past years under the RTG portion of the ANS program has been the design, fabrication, and delivery of the General Purpose Heat Source (GPHS) RTGs, preparation of safety analysis reports, and delivery of radioisotope heater units for the NASA Galileo and Ulysses missions. The delay in the first launch to 1989 added appreciably to the remaining prelaunch activities, particularly in the safety and the RTG testing areas. Since the January 1986 Challenger accident, DOE has been working closely with NASA to prepare new Final Safety Analysis Reports (FSARs) as a result of new launch requirements. While preliminary analyses indicate no problems, confirmatory tests are being run by DOE in FY 1988 to complete the FSARs to support a FY 1989 launch date.

New tests and an extensive set of new analyses--in some cases, using new models--will be required to incorporate the findings from the Challenger and Titan 34D accidents and potential impact on RTG's. Thus, full funding of the safety and technical support organizations as well as the system contract efforts is essential if DOE is to complete the first FSAR in 1988 to support a 1989 launch, and the second FSAR in 1989 to support a 1990 launch.

In addition. there are numerous activities keyed to work on both the Galileo and Ulysses missions as well as the terrestrial RTG program. For example. DOE is protectively storing and monitoring the four flight RTGs for Galileo and Ulysses. DOE is also conducting long-term performance tests ("life tests") on a Qualification Unit to confirm reliability and power predictions for the Galileo and Ulysses missions. The launch delay. coupled with the new upper stage for Ulysses. will require an adjustment in the internal structural support of the RTG to hold the heat source modules in place. This is a major operation almost akin to disassembly. reassembly. and acceptance testing on two RTGs. This work will have to be completed in 1988 to support a 1989 launch option for the Ulysses mission. This requires a major resource commitment to the DOE Mound Plant in Miamisburg. Ohio.

In looking to the future. DOE is continuing to pursue the technology and the development of an advanced modular RTG that offers the promise of higher power density and greater size adaptability for the next generation of DOD and NASA missions. such as the Mariner Mark II. The modular concept to be employed on the generator will enable NASA to accommodate a range of interplanetary missions. During 1989, thermoelectric modules will be produced and assembled into a ground engineering system for demonstration tests.

In parallel with the advanced modular RTG development, DOE is continuing its efforts to improve thermoelectric conversion efficiencies, including silicon germanium optimization, electrical contacting, evaluation of materials properties, degradation mechanisms, and material interactions.

In 1989, several laboratories working on heat source efforts will start production activities for the DIPS flight program. DOE will also continue those efforts necessary to improve heat source safety, improve production efficiency to reduce heat source costs, and continue work in long-lead areas. Included is the redesign and design verification of changes to the GPHS-RTG to improve safety and performance for future missions.

To meet DOE obligations to deliver RTGs for terrestrial military missions, the Special Applications program will continue its efforts to develop and demonstrate the necessary technology. During 1987, an engineering demonstration unit was placed on extended life testing, and testing of thermoelectric modules continued. DOE also delivered three 5-watt RTGs in 1987 to DOD under a reimbursable agreement. During 1989, DOE will continue design and integration studies for specific missions, continue testing of the engineering unit and thermoelectric modules to develop reliability data, and complete tooling requirements for modifications at the Mound

Plant for the fueling, assembly, testing, and delivery of a 180-watt RTG late in the fiscal year. DOE will also continue the safety qualification of a small, sealed, terrestrial heat source to meet projected DOD requirements for small RTGs in the early- and mid-1990's.

REMEDIAL ACTION AND WASTE TECHNOLOGY

The principal objective of the DOE Remedial Action and Waste Technology Program is to stabilize radioactive wastes or perform decontamination and decommissioning (D&D) activities at radioactively contaminated facilities and sites across the United States, as authorized by Congress. Successful execution of this program is a key part of the Department's commitment to continue to protect public health and safety and to assure a safe and clean environment in connection with its nuclear operations and activities. In addition, program officials assist State and interstate regional compact officials to develop a nationwide system to successfully manage low-level radioactive waste disposal.

The Remedial Action and Waste Technology Program is comprised of several key activities, including:

- the Formerly Utilized Sites Remedial Action Project (FUSRAP), where DOE manages remedial actions at sites formerly utilized by the Department's predecessor organizations or assigned by Congress;
- completion of remedial actions undertaken at Grand Junction, Colorado, as authorized by Congress pursuant to Public Law 92-314, as amended;
- the Uranium Mill Tailings Remedial Action (UMTRA) Project, where DOE conducts remedial actions at inactive uranium mill tailings sites and several thousand associated vicinity properties in accordance with Public Law 95-604;

- the Surplus Facilities Management Program (SFMP), where DOE manages the cleanup of certain surplus radioactively contaminated DOE facilities principally used in the past to support civilian nuclear energy programs:
- the West Valley Demonstration Project, where DOE will solidify high-level radioactive wastes at the Western New York Nuclear Services Center near West Valley, New York, for final disposal in accordance with Public Law 96-368;
- the Low-Level Waste Program, which, among other things, provides technical assistance to States and regions to assist them in developing new capacities for the disposal of low-level radioactive waste, in accordance with Public Law 99-240; and,
- the Byproducts Utilization Program, which DOE proposes to transfer to the private sector in FY 1989.

The requested funds for the Remedial Action and Waste Technology Program are distributed among the program elements as indicated in the following table.

	Budget Authority ----($ in Millions)----	
Program Element	FY 1988 Appropriation	FY 1989 Request
Remedial Action and Waste Technology		
Formerly Utilized Sites	$ 23.0	$ 22.6
Grand Junction	0	0
Uranium Mill Tailings	111.3	116.0
Surplus Facilities	46.0	47.2
West Valley	54.2	67.1
Low-Level Waste	5.0	5.0
Byproducts Utilization	5.0	0
Program Direction	2.3	2.4
Total	$ 246.8	$ 260.3

FORMERLY UTILIZED SITES REMEDIAL ACTION PROJECT

FUSRAP is comprised of remedial actions at former nuclear processing facilities which became radioactively contaminated as a result of former Manhattan Engineer District or Atomic Energy Commission (MED/AEC) activities and which have not been decontaminated sufficiently to meet current public health and safety guidelines. FUSRAP also includes certain contaminated sites specifically assigned to DOE by Congress for remedial action. The Department's Oak Ridge Operations Office has the lead field management responsibility for implementing FUSRAP.

To remedy the situation at these contaminated sites, either the contaminated material will be stabilized in place, with restrictions placed on the use of the site, or the contamination will be removed and disposed of at another location. Legislative authority derived from the Atomic Energy Act of 1954 permits DOE to conduct these needed remedial actions. Radiological surveys of potentially contaminated sites, which were identified during a 1987 records review, will be completed in FY 1988. The results of these surveys could lead to several more sites being added to the program.

Congress added four sites to the program when it enacted Public Law 98-50, the FY 1984 Energy and Water Development Appropriations Act, and directed that DOE initiate a decontamination R&D project at these sites as a priority action. With enactment of Public Law 98-360, the FY 1985 Energy and Water Development Appropriations Act, Congress directed DOE to reacquire the former St. Louis Airport site and use it to dispose of waste from the cleanup of the nearby Latty Avenue site and vicinity properties. Congressional and Departmental additions bring the current number of sites in FUSRAP to 29.

In FY 1987, the Department initiated and completed cleanup work at the National Guard Armory in Chicago, Illinois. The waste materials generated by this effort were shipped for disposal to DOE's Hanford Reservation in the State of Washington. The Department also began remedial actions at the Albany Research Center in Albany, Oregon. During the year, approximately 2,700 cubic yards of waste material plus four truckloads of contaminated equipment were disposed of at DOE's Hanford Reservation.

Decontamination actions at Maywood, New Jersey, continued in FY 1987. The general approach to these projects is to give priority to the cleanup of contaminated residential properties and to store the waste temporarily on each processing and storage site. The cleanup of residential properties in Maywood, contaminated with material from the Stepan Company site, was completed in FY 1985, along with some residential properties in the adjacent town of Lodi found to be contaminated from the Stepan site. In FY 1986, the contamination from the Stepan site was found to be more extensive, extending into Lodi and under New Jersey Route 17. Extensive radiological surveys and characterizations of these contaminated areas were conducted in FY 1987 to assess the contamination boundaries and estimated waste volumes. All excavated wastes are being stored on an 11.7 acre portion of the Stepan Company property at Maywood, which Stepan donated to DOE in 1985.

At Wayne, New Jersey, the cleanup of Sheffield Brook and residential properties bordering the brook was completed in FY 1987. Remedial actions at this site are now complete until such time as a disposal site for the waste is established in New Jersey. A Memorandum of Agreement is being developed with the State of New Jersey to cooperatively identify candidate locations in the State for DOE to establish a site for the disposal of an estimated 120,000 cubic yards of waste at Wayne, as well as an estimated 360,000 cubic yards of FUSRAP waste now located in Middlesex and Maywood, New Jersey.

At Colonie, New York, DOE acquired the former National Lead Industries site by donation in February 1984, along with two adjacent parcels owned by the Niagara Mohawk Power Company that have waste buried on them. Designation surveys for the 58 Colonie vicinity properties were completed in 1987. Remedial actions at 35 of the 58 vicinity properties were conducted in 1984 and 1985. The remaining 23 vicinity properties will be completed in 1988 and the waste from these properties is being temporarily stored inside the plant. In FY 1987, DOE initiated site characterization and chemical stabilization of areas previously defined in FY 1986.

In 1988, the Department plans to conduct expedited actions at the Seaway, New York, site to provide for long-term, in-place management of the waste. The Certification Docket for the site will be issued in 1989.

In 1988, we plan to conduct public scoping meetings prior to conducting a Remedial Investigation/Feasibility Study (RI/FS) for the four New York sites--Colonie, Linde, and Ashland 1 and 2--under CERCLA. The RI/FS will also satisfy NEPA requirements. Site characterization at all the sites will be completed in 1989, and the remedial investigation report will be published in early 1990. The Ashland 1 and 2 sites could be added to the Superfund National Priorities List in 1988 and, in anticipation of this, we are closely coordinating our activities with Environmental Protection Agency (EPA) and the State of New York.

FY 1987 activities at the FUSRAP sites in Missouri included characterization at the Latty Avenue and St. Louis Airport sites and vicinity properties. The Department completed a study for the St. Louis Airport site and determined that the site plus additional adjacent property would be suitable for the disposal of waste from the St. Louis Airport. Latty Avenue. and the downtown St. Louis sites and vicinity properties. The Department is working with the City of St. Louis to reach agreement on the transfer of this property to DOE. Subject to agreement with the City on the land transfer. we will initiate public scoping for the environmental documents for these three sites. We are also working with EPA to prepare a Federal Facilities Compliance Agreement for our activities at these sites. FY 1988 activities will include radiological and chemical characterization at the three sites.

A revision to the FUSRAP Project Plan was prepared in FY 1987. A preliminary total cost estimate of $960 million has been made for the current 29-site FUSRAP program. based on completion of all the work early in the next century.

GRAND JUNCTION REMEDIAL ACTION PROJECT

Under Title II of Public Law 92-314, Congress authorized financial assistance to the State of Colorado to limit radiation exposure resulting from the use of uranium mill tailings for construction purposes in Grand Junction. Colorado. This cooperative effort is administered by the Colorado Department of Health through DOE’s Grand Junction Project Office. The remedial action provides for the removal of uranium mill tailings from the premises of 593 structures where concentrations of radioactive radon and its decay products exceed guidelines established by the Surgeon General. Congress enacted Public Law 95-236 to extend the time (which has now expired) for property owners to apply for inclusion in the Grand Junction Remedial Action Project and increase authorized funding for the project. Federal funds cover 75 percent of project costs. with the State of Colorado providing the balance. Remedial action was completed in FY 1987. with final radiological verification scheduled for completion in FY 1988. In FY 1988 the project will be closed out by certifying the completion of all vicinity property remedial actions.

URANIUM MILL TAILINGS REMEDIAL ACTION PROJECT

Public Law 95-604. the Uranium Mill Tailings Radiation Control Act of 1978. assigned to DOE the responsibility for conducting remedial action at 24 former uranium ore processing sites and several thousand contaminated vicinity properties. Nine of the sites are designated as high priority.

six as medium priority, and nine as low priority. The Act provides authority for remedial action by the Department for a period of 7 years following promulgation of standards by the EPA, which occurred in March 1983.

The Department has proposed to extend the 7-year authorization period until the end of FY 1994, consistent with the recommendation to extend the duration of the project made by the House Committee on Appropriation in House Report No. 99-195. Legislation was introduced in the Senate (S. 1991) just prior to the end of the first session to accomplish this needed extension. We expect a companion bill will soon be introduced in the House to extend the UMTRA Project authorization period and our FY 1989 budget request identifies resource requirements to meet this extended schedule. The proposed extension takes into consideration the actual project experience gained in performing remedial action at several processing sites and many vicinity properties. Project plans have been revised to reflect this experience, and are based on the following key assumptions: (1) 4,800 of the 8,156 designated vicinity properties will actually require cleanup in accordance with EPA standards: and (2) eight of the tailings piles (located in or near Durango, Grand Junction, Rifle, and Naturita, Colorado: Belfield, North Dakota; Lakeview, Oregon; Salt Lake City, Utah: and Riverton, Wyoming) will be relocated.

The program strategy is to focus near-term activities on the higher priority sites and on vicinity properties. Remedial actions are being conducted in accordance with cooperative agreements negotiated with the affected States and Indian tribes. Federal funds cover 90 percent of the remedial action costs (100 percent for those sites located on Indian lands), with the States providing the remaining 10 percent. The type of remedial action for the processing sites will be to stabilize the mill tailings in place, where possible, or to remove them to a new disposal site. In either case, the final disposal sites will be Federally owned and maintained under a license issued by the NRC. Engineering plans and environmental documents are prepared for each site cleanup and disposal operation. Concurrence by the NRC and the affected State or Indian tribe is required for the remedial action plan at each site. The project also involves the cleanup of an estimated 4,800 contaminated vicinity properties (mainly in the Grand Junction, Colorado, area but not covered by the Grand Junction Remedial Action Project). The Department's Albuquerque (New Mexico) Operations Office has been delegated the responsibility for implementing the UMTRA Project.

On January 5. 1983. EPA issued final standards for the disposal and cleanup of the inactive mill tailings sites that comprise the UMTRA Project. These standards were challenged in 1985 before the Tenth Circuit Court of Appeals. The court subsequently set aside EPA's groundwater standards and ruled that EPA must issue new standards of general applicability. On September 24. 1987. EPA issued its proposed rule. Substantial additional funds would be required to meet the proposed standards. We anticipate that the EPA will issue final standards in March 1989.

The Administration is concerned that costs of remedial actions to clean up inactive uranium mill tailings and sites have greatly increased beyond that intended when Public Law 95-604 was passed. The Administration will work with the States and Federal regulatory agencies to assure that an effective but cost constrained cleanup program is undertaken so as to limit unnecessary cost growth. The Administration has adopted a policy affirming its commitment to pay 90 percent of the cost of these projects up to the current estimated total DOE cost of $925 million. As part of the 1989 Budget Submission, the Administration proposes that Congress revise Public Law 95-604 to establish a new cost-sharing formula that will clearly define and limit Federal funding. The legislation would provide that no Federal funds could be expended above current cost estimates unless clear improvements in public health and safety could be demonstrated.

Specific accomplishments in FY 1987 included the completion of 24 percent of the remedial action at Durango, Colorado; 75 percent completion of the remedial action at Lakeview, Oregon; 89 percent completion at Salt Lake City, Utah; 100 percent completion at Shiprock, New Mexico; and 10 percent completion at Tuba City, Arizona. Construction management of the remedial action at the Salt Lake City processing site is being carried out by the State of Utah. The approach at this site is to relocate the tailings to a site near Clive, Utah. Remedial action was initiated in FY 1987 at the Durango and Grand Junction, Colorado, sites. Cleanup continued at high-priority vicinity properties near the sites at Durango, Colorado; Salt Lake City, Utah; Grand Junction, Colorado; Edgemont, South Dakota; Lakeview, Oregon; and Shiprock, New Mexico. Remedial action was completed on 970 vicinity properties during FY 1987.

During FY 1988, work is underway or planned at nine processing sites. The work at Salt Lake City, Utah. and Lakeview, Oregon, will be completed. Onsite work will continue at Ambrosia Lake, New Mexico; Durango, Colorado: and Tuba City, Arizona. Processing site remedial action will begin at Green River, Utah: Grand Junction, Colorado; Rifle, Colorado; and Riverton, Wyoming. Remedial action on an estimated 891 vicinity properties will also be completed.

During FY 1989. remedial action will be underway at 8 processing sites and an estimated 846 vicinity properties will be completed. Remedial action will be initiated at the Spook. Wyoming site. Remedial action will be completed at the Green River. Utah; Spook. Wyoming; and Tuba City, Arizona. sites. Site remedial action will be continuing at Ambrosia Lake. New Mexico: Durango. Grand Junction and Rifle. Colorado: and Riverton. Wyoming. Surveillance and maintenance activities will be conducted at completed sites (Canonsburg, Pennsylvania: Lakeview. Oregon; Salt Lake City, Utah: and Shiprock. New Mexico).

SURPLUS FACILITIES MANAGEMENT PROGRAM

This program provides for the safe management and disposition of certain surplus facilities radioactively contaminated from DOE civilian nuclear energy development activities. The decontaminated facilities and sites could eventually be returned to productive use as a result of our remedial actions. To date. the Surplus Facilities Management Program has been responsible for 70 projects. Thirty-seven of these have been removed from the inventory through remedial actions or transfers, and 33 projects remain in the current inventory. Priorities are established and project schedules are developed within available funding, through analysis of public health and safety. legal. economic. and work continuity factors for each site. The DOE Office of Nuclear Energy is responsible for program management of the SFMP.

Decommissioning of the Shippingport Atomic Power Station continues. Dismantling of the plant began in September 1985 and will continue through project completion in early FY 1990. Preparation for the removal of the reactor pressure vessel began in FY 1987. The vessel was filled with concrete and is scheduled to be shipped by barge to the Department's Hanford Reservation for disposal as low-level waste in FY 1989. The Department is cooperating with the NRC and EPRI in obtaining samples and components of the plant for aging studies. The Department is also participating in an international exchange of decommissioning technology sponsored by the Nuclear Energy Agency (NEA). The NEA program includes the Shippingport decommissioning and West Valley demonstration projects in the

United States, as well as eight significant decommissioning projects in other NEA-member countries.

The Department has negotiated a Federal Facilities Agreement with EPA for the Weldon Spring Site Remedial Action Project, which involves decontamination and decommissioning of the 222-acre Chemical Plant (which includes the 53-acre raffinate pit area) and a 9-acre limestone quarry used for the disposal of TNT. DNT, and radioactive wastes. EPA added the Weldon Spring Quarry to the Superfund National Priorities List in 1987. A Draft Environmental Impact Statement (DEIS) for Weldon Spring was published last year and identified the Department's preferred alternative as on-site disposal of the D&D waste. A significant amount of new contamination was found after the DEIS was issued. and the Department decided last June to revise the DEIS following a more detailed site characterization. In December 1987, EPA requested that DOE prepare an RI/FS instead of an Environmental Impact Statement to meet NEPA and CERCLA requirements. DOE is presently developing the schedule for completing the RI/FS. Activities in 1988 include (1) completion of the chemical and radiological characterization: (2) conceptual engineering to support the RI/FS: and (3) initiating certain expedited actions designed to eliminate potential health and safety hazards (such as dismantling deteriorating buildings. removal of PCB transformers and outside asbestos. and storage or removal of old chemicals).

The Power Burst Facility (PBF) in Idaho was added to the inventory of SFMP projects at the beginning of FY 1987. Later in FY 1987. Congress determined that the PBF should be used in conjunction with cancer treatment research projects. Responsibility for the facility has been transferred to the DOE Office of Energy Research for reactivation and SFMP funds identified for decommissioning activities in FY 1988 were transferred to the Office of Energy Research for this important project.

Work on the decontamination of plutonium-contaminated facilities at Mound Laboratories in Miamisburg, Ohio, is behind schedule due to identification of additional quantities of contamination. Work is in process and will be continued in FY 1988 and FY 1989. This project was begun in 1978 and will now be completed in FY 1991.

At Monticello, Utah, mill tailings will be removed from 10 additional residential properties in FY 1988 leaving about 16 of the 62 properties to be completed in FY 1989 and FY 1990. These Vicinity Properties are listed on the EPA National Priorities List. The Mill site, itself, is expected to be placed on the Superfund National Priorities List in FY 1988. EPA and DOE have agreed to enter into a CERCLA Section 120 Interagency Agreement covering both the Mill site and vicinity properties to expedite cleanup. The Agreement is expected to be signed in FY 1988. Remedial action is already at the Vicinity Properties and is expected to begin at the Mill site in late FY 1989 following the issuance of a Record of Decision. If a decision is made to relocate the tailings, the project cost and schedule will be significantly impacted.

Decommissioning of the research reactor at the Center for Energy and Environment Research (CEER) in Puerto Rico was delayed in FY 1987 and will be completed in FY 1988. At the Argonne National Laboratory in Illinois, decommissioning of the Experimental Boiling Water Reactor, temporarily delayed in FY 1987 by funding reductions, will continue in FY 1988 and FY 1989.

Other activities in FY 1989 will include continuation of site and facility disposition projects at Santa Susana, California; the Oak Ridge National Laboratory in Tennessee: and the Idaho National Engineering Laboratory in Idaho. At the Los Alamos (New Mexico) National Laboratory, decommissioning of the experimental Ultra High Temperature Reactor will be initiated.

Finally. activities associated with the cleanup of contaminated facilities at the Battelle Columbus Laboratories in Ohio will begin. FY 1989 activities will include characterization of the site, preliminary engineering for cost estimates and design, and the preparation of environmental documentation necessary to begin remedial action.

WEST VALLEY DEMONSTRATION PROJECT

The objective of the West Valley Demonstration Project is to demonstrate the solidification process for the disposal of high-level liquid nuclear wastes under the provisions of Public Law 96-368. the West Valley Demonstration Project Act. An integrated production-scale development and demonstration project for treating high-level liquid nuclear wastes is being carried out at the Western New York Nuclear Service Center, near West Valley, New York.

Major activities being performed as part of this project include (1) decontamination required to prepare existing facilities and equipment to accommodate the solidification project; (2) removal of wastes from underground storage tanks; (3) development, design, construction, and operation of systems and necessary support facilities for the solidification of the wastes: (4) acquisition of containers for the permanent disposal of the solidified waste; (5) temporary storage and transportation of the solidified waste to an appropriate Federal repository for permanent disposal: (6) decontamination and decommissioning of the waste tanks, facilities, hardware. and material used in carrying out the project: and (7) disposal of low-level and transuranic wastes produced from project activities.

The liquid high-level waste will be pretreated and its volume will be reduced in the Supernatant Treatment System. The low-level liquid waste stream effluent from that system will be concentrated in the Liquid Waste Treatment System. immobilized in the Cement Solidification System, and stored in the Drum Cell. During FY 1987 major construction of these four facilities were completed and testing began. Design and fabrication of various systems and components of the Vitrification Facility also continued in FY 1987. The Vitrification Facility will be used to solidify the high-level waste.

Non-radioactive testing of the Supernatant Treatment System, Liquid Waste Treatment System, and Cement Solidification System should be completed in FY 1988. Processing of the radioactive supernatant will then begin. The supernate now stored in underground tanks represents nearly 90 percent of the volume and 50 percent of the radioactivity of the stored liquid waste. The separated radioactive material will be stored and later blended with the sludge from the storage tanks and glass formers prior to being fed into the melter in the Vitrification Facility.

A supercompactor was installed, tested, and began operation early in FY 1988. A contact-handled waste Size Reduction Facility also began operation early in FY 1988. These facilities will give the project the capability to reduce the volume of low-level waste. They will be operated as needed throughout FY 1988.

The Supernatant Treatment System, Liquid Waste Treatment System and Cement Solidification System will be operated during FY 1989 to continue processing of the high-level waste supernatant. Non-radioactive testing of the glass melter, and a substantial portion of the design of the Vitrification Facility will be completed in FY 1989. Fabrication of components and systems for the Vitrification Facility and operation of the Supercompactor and contact-handled Size Reduction Facility will continue. A minimal decontamination and decommissioning effort will also be continued as required to support project efforts.

The current estimated total cost of the West Valley Demonstration Project is $833 million, making the DOE share $750 million. The Administration is concerned with the growth of the Federal commitment for the West Valley Project. Community involvement and court imposed requirements have increased the initial program scope. As part of its FY 1989 budget request, the Administration proposes that Congress amend Public Law 96-368 to establish a "cap" on Federal funding to complete the project. This needed legislation would better define the intended scope of Federal participation in West Valley cleanup activities by establishing a new funding formula for additional expenditures above the authorized limit.

LOW-LEVEL RADIOACTIVE WASTE MANAGEMENT

The Low-Level Waste Program provides technical assistance to States and compact regions in developing new capacity for the disposal of low-level radioactive waste in accordance with Public Law 99-240, the Low-Level Radioactive Waste Policy Amendments Act of 1985. This legislation assigned individual States the responsibility for the disposal of low-level radioactive waste generated within their borders, with the exception of such waste generated as a result of certain Federal activities and non-DOE generated low-level waste exceeding the limits established by the NRC for Class C low-level waste. The formation of regional compacts among States to carry out their responsibilities is encouraged by the Act. Towards that end, DOE administers an escrow account created by the Act, from which payments are made to States that are in compliance with the Act's milestones. DOE determined each State's compliance status for the first milestone that occurred on July 1, 1986, and has developed criteria for the January 1, 1988, milestone. DOE is currently evaluating each State and compact region's request for escrow account funds and will disburse rebates according to whether those States and Compact regions had complied with the latest milestone.

During FY 1988, the Low-Level Waste Program will conduct the various reporting and administrative activities required in the Act and will focus on meeting the generic technical needs of the States and compact regions as they work to select sites and develop new disposal facilities. Specifically, the Department plans to concentrate on assisting States and regions in evaluating alternative disposal technologies to those in practice at the currently operating sites in Washington, South Carolina, and Nevada. An evaluative study and workshop on known characteristics of alternative disposal technologies were conducted. DOE plans to submit a design report of two such alternatives to the NRC for a licensing review. The program will also continue to monitor the development of innovative waste treatment methods in the private sector. The Department has submitted a report to Congress on disposal of greater-than-Class C low-level waste and will continue to carry out responsibilities assigned to it for such disposal under the Act. Reports on State and compact region progress and the use of escrow account rebate funds will be submitted to Congress in FY 1988, as required by the Act.

In FY 1989, the Low-Level Waste Program will continue to provide technical assistance to States and regions to support the selection and development of new low-level disposal facilities. It will follow the correction of problems and stabilization at existing disposal sites and assess innovative methods for the treatment and disposal of low-level waste. In FY 1989, the Department will implement its recommendations to Congress on low-level wastes exceeding NRC's Class C limitations. The Department will also continue to carry out its administrative and reporting requirements to Congress.

BYPRODUCTS UTILIZATION

In FY 1986. Congress directed DOE to initiate a civilian byproducts utilization program that emphasized food irradiation applications. The goal of this program is to develop and transfer the technology for the beneficial use of nuclear materials. Irradiation of food and other agricultural commodities will be emphasized in cooperation with States and other Federal agencies. In 1987. DOE signed cooperative agreements with all designated organizations for the development of commodity irradiation projects in Oklahoma. Hawaii. Iowa. Florida. Washington. and Alaska. These States were selected based on their proximity to major agricultural commodity production and processing centers and the potential benefits to be derived by their use of food irradiation processing. The DOE program will also focus on developing an adequate U.S.-based supply of irradiation sources for commodity irradiations. Plans for the irradiator facilities will be developed to demonstrate that irradiation of agricultural commodities can be a beneficial and a unique method of processing and preserving food groups. The project sponsors will be responsible for developing an integrated regional plan that includes (in addition to DOE) the involvement of such organizations as regional universities, agricultural research groups, regulatory agencies, suppliers of agricultural commodities, food processors, and market testing groups. No FY 1989 funding is being requested to continue this activity and the Department will assist the project sponsors in obtaining from States and the private sector sufficient resources to continue development of the six regional facilities.

WASTE TREATMENT

In FY 1988, DOE plans to complete a collaborative program with the Federal Republic of Germany to produce 30 heat and radiation sources for testing purposes in the West German radioactive waste repository program. The civilian waste treatment research and development program at the Pacific Northwest Laboratory will be phased out, the radioactive waste vitrification system placed in a safe standby condition, and documentation of research and development findings to date completed. No funds were requested for this program in FY 1988 and FY 1989.

DISCUSSION

Mrs. **Lloyd**. As you know, Ted, I live down in Tennessee where we're trying to get several reactors, back on line, and one of the things we consider is that we have to consider evacuation routes and sheltering, and other safety precautions.

It's my understanding for all the accidents that are really currently being considered in power plant licensing, that the HTGR reactor technology does not have a failure mode that will lead to the offsite radiation releases requiring this sort of evacuation or sheltering. Is this correct?

Mr. **Garrish**. That is one of the advantages that has been often cited for the HTGR reactors.

Mrs. **Lloyd**. Well, is this the case for the other advanced technologies that are receiving this funding?

Mr. **Garrish**. Well, the liquid metal has the same potential in terms of passive safety features. We are, of course, also doing research into the other advanced reactor concepts in the light water area.

They also provide the potential benefit of providing some safety features, and this is an important area that we continue to look at. It is something that has been emphasized in our budget.

Mrs. **Lloyd**. Well, let's go back. Isn't the answer to the question that I asked you no?

Mr. **Garrish**. I'm sorry?

Mrs. **Lloyd**. Isn't the answer to the question I asked you no?

Mr. **Garrish**. Well, I'm not sure that I could say that completely. I would say that one of the advantages that the high temperature gas reactor has, that it does have the passive safety features which could lead to a future breakthrough, and it's one of the issues that make it attractive for future activities.

Mrs. **Lloyd**. Would you answer this for the record, please?

Mr. **Garrish**. Yes, I'd be happy to.

[Information to be furnished follows:]

Advanced HTGR and LMR concept development activities funded by DOE were initiated with the objective of incorporating passive safety features into reactor designs that would minimize reliance on complex engineered safety systems and reliance on operator actions for off-normal events. Significant progress has been made in this regard. Both concepts meet NRC advanced reactor policy guidelines, and both provide substantial margins of safety beyond the limits established by NRC licensing requirements. The use of inherent reactor shutdown and heat removal systems for both the HTGR and LMR are intended to provide assurance that there is simply no threat to the public should there be a major failure in the reactor.

Mrs. **Lloyd**. Because if this is true, then my question is why are we investing in technologies at the expense of HTGR when the goal of this Committee is to get technology to the marketplace?

Mr. **Garrish**. This has certainly been a theme this year throughout the budget hearings I have had and the number of people that have talked to me about our programs. There has been concern about the amount of money that we are spending on our light water program, and how little we are spending on our gas reactors.

I would say that the important aspect of our light water program is that we have a very huge investment out there, and there are safety features which could possibly be adapted, and we have a program to try to get through some of the institutional barriers of that program. And, therefore, we think it's important that we continue with our Light Water program.

On the other hand, not only do we have to have a "present" with our program, but we need to have a "future", and these advanced reactors, the liquid metal and the gas reactor, offer opportunities that need to be explored. And the question is really the level of funding.

At this stage we do believe that the levels that we have proposed are appropriate.

Mrs. LLOYD. Well, I would like for you to go into detailed answer on the previous question I asked you for the record.

[Information to be furnished follows:]

The demand for electricity, the needs of the marketplace, and the availability of proven reactor designs will determine which, if any, nuclear reactor technology is selected to meet a portion of this country's future energy needs. Even with a clear need for new generating capacity, a utility may not be willing to order a new nuclear powerplant unless there is some certainty in the licensing process. Overcoming the institutional obstacles presently confronting nuclear power is a prerequisite to the deployment of any advanced reactor.

The Department's Advanced Light Water Reactor (ALWR) program is designed to help resolve many of these institutional issues, including those that have severely escalated costs and damaged public perception. The large (1,300 MWe) ALWR task is specifically focused on obtaining Nuclear Regulatory Commission (NRC) certification of two plant designs by 1991. Once the NRC certification process is established, a major institutional hurdle will have been removed, and utilities might then select one or more nuclear plant designs when they decide to add new generating capacity.

Several candidates exist in addition to the large ALWR. Innovative mid-size (600 MWe) LWRs and the advanced modular liquid metal reactor (LMR) and the modular high temperature gas reactor (HTGR) systems each show potential to help overcome concerns over current LWR technology. The Department has a balanced program to revitalize the nuclear option while actively developing all three technologies.

The mid-size (600 MWe) ALWR design is an extension of the proven LWR technology, has a broad base of industry and utility financial support, and can proceed directly to commercial deployment in the 1990s without the need for prototype testing. The Department is working cooperatively with industry, through the Electric Power Research Institute, to develop a set of standard requirements for the next generation of LWRs. Once established, these requirements will guide the reactor manufacturers in developing NRC certified designs that will meet utility needs.

The HTGR would probably require a safety demonstration of a full-scale prototype and probably would not be available for subsequent deployment until after the year 2000. The HTGR conceptual design is now undergoing NRC review to identify any fundamental licensing issues that would require further definition and resolution. The requested FY 1989 funding will maintain the established technology base pending completion of NRC review and definition of issues. Given the current status of HTGR technology, it is more prudent to defer any significant expenditure of R&D funds until after this review is complete and R&D priorities can be defined.

The advanced liquid metal-cooled reactor (LMR) has similar potential to secure safe, economic nuclear power. However, the LMR requires extensive, additional development work before it can be considered a practical option for the marketplace. The focus of LMR development is on the modular, Integral Fast Reactor (IFR) concept which uses a metal fuel cycle integrated on-site with the reactor plant. The technology to support the anticipated inherent safety and economic breakthroughs of the IFR concept is not expected to be demonstrated before FY 1993, even at the current requested funding level.

Mrs. LLOYD. Turning to another area, I was looking at the 1989 budget request in detail today, and I noticed that there was no continued funding for the advanced instrumentation and control development efforts, such as ACTO at ORNL. Have these activities been completed?

Mr. GARRISH. Those activities have not been completed in the sense, I believe, that you are suggesting. They are future-oriented control technologies that we need to explore. However, this simply is a matter of budget priorities. There's a lot of work that's currently being done on this in other fields, and we have felt that, in light of the priorities that we have this year, that it did not measure up to the other needs that we had in the program.

Mrs. LLOYD. In other words, you have not put a high priority on ACTO?

Mr. GARRISH. For the budget this year, we don't think that the kind of return that we could get in the budget matches some of the other programs that we have.

Mrs. LLOYD. As the request for the Advanced Reactor R&D program represents a $38 million reduction from the 1988 budget, I was just trying to determine the particular activities that are being terminated, and what are completed, and what really needs to be completed.

What sort of impact, Ted, would these reductions have on contractor support, for instance, such as advanced LMR design activities, and the sustaining of other essential LMR facilities operations?

Mr. GARRISH. Well, the question, the way I understand what you are asking, relates to the facilities budget, and whether or not we have sufficient facility to carry on with our program. We believe that the level that we are at currently is about as low as you can go and still maintain a viable program.

Mrs. LLOYD. I think what I'm trying to get at, is there a balance, an appropriate balance between the program funding and the facility support?

Mr. GARRISH. We think that the facility support numbers will support our programs. I think we are probably at the very minimum with that amount, and it is a matter of how we can go forward, move forward with our programs at what level.

Mrs. LLOYD. It appears also, looking at the budget, the Department has made the decision to develop core designs based upon the metal-fuel concept rather than the oxide; is that correct?

Mr. GARRISH. That is correct.

Mrs. LLOYD. What are the goals of the remaining oxide fuel development under the agreement with Japan?

Mr. GARRISH. If I could, I'd like to ask Dr. Bunch to respond to that question.

Mrs. LLOYD. For the record, it's Dr. Delbert Bunch. Please proceed, Dr. Bunch.

Dr. BUNCH. We still have a substantial amount of oxide work underway. The Fast Flux Test Facility has, as part of its program activities, the conduct of a program called the Core Demonstration Experiment, which has as a purpose the testing of extended lifetime and better performance.

There are a number of other programs in which we have cooperative arrangements with the Japanese, and with the British, for transit testing. These will be continued. Clearly there are program opportunities which we won't be able to pick up in this area until such time as we have been able to see what the promise of this metal fuels program will be.

Mrs. LLOYD. What I am trying to get at is what is the objective? What is your objective? Can this cooperative arrangement with the Japanese, for instance, be changed from the oxide fuel to the metal fuel agreement? Has it undergone peer review?

Dr. BUNCH. We have been involved in discussions with the Japanese, PNC, for the purpose of extending the Memorandum of Agreement of cooperation with the Japanese government to cover the whole gamut of cooperative programs with the Japanese and the breeder reactor and liquid metal reactor area.

The objective of this whole set of programs is to try to engage the Japanese and ourselves in activities which will preserve the liquid metal technology option for both the United States and Japan.

Mrs. LLOYD. Well, now, has the metal fuel program over the oxide program undergone peer review?

Dr. BUNCH. I think it would be unfair to characterize it as a choice of metal fuel over oxide fuel. In fact, I think what's happened is we have reached the point in which the oxide fuel has shown its potential, shown that it's a practical system, and what we are exploring here is an alternative system which may in fact have some opportunities in the areas of both safety, as well as economics, and it's that area we are trying to explore.

Mrs. LLOYD. Well, you stated earlier now that the Department has decided to develop the core design based upon the metal fuel concept rather than the oxide fuel concept. That was the first question I asked.

Dr. BUNCH. The Core Design Experiment that I spoke of is an oxide fuel system. That program will be complete in the next few years. What we are talking about is having completed that activity, shown that that technology is fully proven, it would be useful to then proceed with the completion of the metal fuels activity.

Mrs. LLOYD. Well, now, last year, if you remember, I asked the Department to prepare a report on the accomplishments of the oxide fuel program. This program has received a tremendous amount of money over the liquid metal technology. As yet our Committee has not received this report. Are you planning to submit this report?

Mr. GARRISH. There are a number of requests and for reports in terms of information that the Committee has indicated to me that they would like to have forwarded to it, and we are prepared to do that, and make those available to you as expeditiously as possible.

Mrs. LLOYD. Well, I'm not trying to be argumentative, but we do really have to assess our priorities at this time, and that's why the report would be so useful.

Thank you very much.

I would like to ask, without objection, that Mr. Morrison's opening remarks be inserted in the record at the proper point in our hearing, and at this time the Chair recognizes the Honorable Sid Morrison.

Mr. MORRISON. Thank you, Madam Chairman.

I opted to run over and vote instead of getting here for the opening of the session.

Could we maybe step back away from specifics into a more general arena just for a moment. I always like to think that the Subcommittee and the Committee should be looking at where really are we headed, as you would see it, and when do you see the Light Water Reactor program bearing fruit? I know that's a little tough to predict, when we will see orders again, and what sort of a timeframe then would that program fit as opposed to the advanced reactors. When do you foresee possibly a liquid metal reactor or HTGR beginning to fit into the commercial scenario? Are we pretty well filling in what it appears America's needs will be?

Mr. GARRISH. In terms of reactor orders, I think that our electricity situation should require enough growth that we need to begin examining that question in terms of future orders some time in the mid-1990's, maybe a little bit sooner. So we will have to begin at that time, begin to assess the question of what type of reactor is the industry most likely to order.

The information that we have been provided indicates to us that that initial order will probably be light water, and the high temperature gas reactor does offer some potential, but we are not yet at the stage to know whether or not we are going to have the kind of impediments and institutional barriers at the NRC to be able to design a reactor and deal with the problems in order to really decide whether an order is appropriate in that field.

As far as the liquid metal reactors are concerned, they are off in the future even farther. So I think that the answer to the question is that the first reactors that are most likely to be ordered will be the light water reactor.

Mr. MORRISON. And the work that we are doing, that you are requesting, is sufficient to meet what you see as demands in that area?

Mr. GARRISH. We believe that it is. It does deal with reactor designs that are currently in hand, and are the most likely candidates for the next order.

Mr. MORRISON. I guess I have to express some concern and a certain amount of self-interest in this. With the reductions in funding and consequently staffing levels that some of the facilities I've watched at FFTF, for instance, staffing level over the last few years lowered by 36 percent, and I notice the same thing both in Idaho and in California, and I'm wondering how far can we go with these reductions, as you squeeze back these programs before safety and effectiveness begin to be impacted?

Mr. GARRISH. Well, in terms of safety, I think that our view on that is that we would not be in any position to reduce personnel that would in any way jeopardize public health and safety. As far as the future of the programs are concerned, in terms of facilities, were we to drop our facility account back even to a lower degree than it is currently in this budget, we may have to be in a position where we would eliminate some of the programs. But I do think that with the budget that we have currently proposed, we can continue, for instance, the FFTF can continue to operate. We have some difficult questions to answer with regard to funding for the future, but I think we are prepared to go through those questions and deal with those issues as they arise.

Mr. **Morrison**. Do the folks at OMB provide the major incentive for you to trim back on these programs?

Mr. **Garrish**. Well, I think we are all trying to grapple with the budget question and deal with the realities of the budget summit. So I wouldn't say that it's completely the problem of OMB, but I think it's something that we all have to grapple with, in terms of what are our realistic priorities for this program.

Mr. **Morrison**. Sometimes I get the impression that they squeeze you folks too. I'm convinced that you know what you're doing; I'm not so sure they do, except as they drive toward a bottom line. And very frankly, I have to admit that some of these programs can be taken to a point that in fact they are rendered essentially ineffective.

Mr. **Garrish**. And I think that that's something that we need to evaluate as we come forward with the budget, and the question that you have to face is if we're not going to do these programs right, we shouldn't do them at all. So it's a question of, "Do we have sufficient funds in order to do the programs right?"

Mr. **Morrison**. And, of course, part of the function of this subcommittee is to make sure that we're telling the rest of the Congress and the Nation that in fact we are doing the research that will lead to future energy sources. I don't argue with you, I certainly argue with the folks downtown, and if there's some point where we collectively can be part of an effort to convince them of the absolute essential nature of a number of these programs.

I wanted to ask one other question, and then I'd like to submit some questions in writing because of the pressures of time.

I find tremendous interest in the isotope production, as we are using more and more of these marvelous materials. I'm wondering what your plans are as far as the future on isotope production is concerned.

Mr. **Garrish**. Well, this falls in the same category as our earlier discussion. It is one of those programs that has been begun in our byproduct area. It does not come up to the same priority as some of our other programs that we are currently going forward with.

In the byproduct area, as you know, we spent about $15 million to date out of a $36 million program, and it is a program, however, that the private sector should be—is fully proven and should be able to continue into the future. So the question was whether or not we would continue to go forward with that program this budget, and the decision was that we were not in a position to do that.

Mr. **Morrison**. Perhaps we can provide a little help.

Mr. **Garrish**. Well, I have to tell you, it is a very difficult issue, because it's a program that was basically half funded, it's already started. You have authorized it. It was a very difficult decision as to whether or not we had the additional funds to be able to complete the program, and it was the judgment that we just did not have sufficient funds in order to fund that program this year.

Mr. **Morrison**. Okay. Well, thank you, Madam Chairman, for the time. And there are a lot of questions in this program area, so, I'd like to submit some in writing. Thank you.

Mrs. **Lloyd**. Well, thank you, Mr. Morrison. And both of us do have many more questions we could ask today, and in the interest of your time as well as ours, we will excuse me, and ask you to reply to questions in writing.

Thank you very much for being with us today.

[Questions and answers for the record for Mr. Garrish follow:]

QUESTIONS FROM CHAIRMAN MARILYN LLOYD

Question 1: What are the advanced reactor programs criteria for budget priorities among the advanced reactor programs?

Answer: Tasks that will make the greatest contributions toward achieving the goals of the Department's Civilian Reactor Development program receive the highest priorities for allocation of limited resources. These goals are:

- To provide an effective and predictable regulatory and institutional environment that enables nuclear power projects to compete freely in the marketplace.
- To support and facilitate industry-led technology efforts to revitalize the Light Water Reactor (LWR) option for the U.S. and to ensure its long-term availability as a vital component of the national energy supply system.
- To explore the feasibility and practicability of advanced nuclear reactor systems with the potential for breakthroughs in economics, safety, licensability, and waste management options.

Answer 1
(continued):

- To support long-term national interests by: conducting cooperative international nuclear R&D projects that further U.S. nonproliferation objectives strengthening our position in international commerce, involving key universities in nuclear R&D utilizing DOE facilities as appropriate and providing options to meet longer term needs to extend uranium resources.

The Advanced Light Water Reactor program is focused primarily on the first two goals, while the Advanced Reactor R&D program concentrates on the second two goals. Within the Advanced Reactor R&D program, the emphasis is on identifying and confirming the potential for significant breakthroughs in economics, safety, licensability and waste management options.

QUESTIONS FROM CHAIRMAN MARILYN LLOYD

Research and Development

Question 2:	Do management plans exist for each of the advanced reactor programs? If not, why not? If so, please submit them. Whether or not they exist, please characterize the management process that would lead you to a $27 million program in near-term light water reactor technology and $7.7 million for intermediate-term HTGR technology?
Answer:	The setting of program priorities and the allocation of funding levels is accomplished through the Federal budget process. The general criteria used in the budget process to evaluate and prioritize funding levels for civilian reactor development programs are those provided in the answer to the previous question (Question 1 from Chairman Marilyn Lloyd). The budget request may not provide an optimal level of funding for individual projects or programs, but would, if approved, provide for significant progress on key programs. With the availability of safe, standardized advanced LWRs and a modernized regulatory process, nuclear power can compete effectively with other energy options. Our LWR activities complement a much larger industry-led effort to bring forth a new generation of nuclear reactors. The modular HTGR conceptual design is currently undergoing NRC review to assure that there are no safety or regulatory issues that would fundamentally alter the prospects for a commercially viable modular HTGR. Funding at much greater

Answer 2
(continued): levels than $7.7 million per year can be deferred pending an assessment of the results of the NRC reviews.

QUESTIONS FROM CHAIRMAN MARILYN LLOYD

Question 3: How much money in the budget is proposed to be spent on the 1300 Megawatt Reactor concept and why would you propose such funding considering it is near-term technology and the unlikelihood of a domestic order for such a reactor?

Answer: The budget request for the large Advanced Light Water Reactor program, which supports obtaining Nuclear Regulatory Commission certification of two 1000-MWe class designs, is $6.5 million.

Overcoming the institutional obstacles presently confronting nuclear power is a prerequisite to the deployment of any advanced reactor. One key to achieving this goal is the establishment of the NRC design certification process. The large ALWR program is the principal vehicle for addressing this and related institutional issues.

QUESTIONS FROM CHAIRMAN MARILYN LLOYD

Question 4: How much money is provided by each of the cost sharing parties for each of the advanced reactor technologies?

Answer: The two Liquid Metal Reactor (LMR) conceptual design contracts with General Electric Company (GE) and Rockwell International (RI) for the Power Reactor Inherently Safe Module (PRISM) and Sodium Advanced Fast Reactor (SAFR) concepts expired December 31, 1987. The only ongoing work pertaining to these designs is under a Program Research and Development Announcement that requested bids for analyzing and upgrading the PRISM and SAFR designs. None of the five successful bidders is operating currently on a cost-sharing basis. However, the Request for Proposals for development of an advanced LMR concept requests private sector cost sharing for this next phase of the LMR design.

During the 3 years prior to expiration of the contract, GE and RI did operate on a cost-sharing basis. GE spent the contract equivalent of $1.7 million on commercialization and market analysis activities and relinquished about $1.4 million in fees. RI supported its commercialization and Institutional Advisory Committee during the 3 years with about $400 thousand of corporate funds and relinquished about $1.1 million in fees with the no-fee contract.

Answer 4 (continued):	With regard to the modular High Temperature Gas Reactor (HTGR) technology, potential users and vendors continue to invest private funds toward the technology and development of the HTGR. In FY 1988, General Atomics and Siemens/Interatom are investing over $5 million, and U.S. utilities are investing $3 million through Gas Cooled Reactor Associates for a total of $8 million.

QUESTIONS FROM CHAIRMAN MARILYN LLOYD

Question 5: Please describe the level of international participation in the advanced reactor programs?

Answer: In cooperation with foreign partners, DOE has undertaken efforts regarding oxide fuel and advanced fuel cladding material testing with the Japanese Power Reactor and Nuclear Fuel Development Corporation (PNC) using FFTF and JOYO: irradiation testing of U.S.- and Swiss-fabricated carbide fuel using FFTF; completion of the UKAEA/DOE PFR-TREAT Agreement with two oxide fuel safety tests in TREAT; operational reliability testing of oxide fuel in EBR-II with PNC; LMR physics measurements with PNC using ZPPR; development of a centralized reliability data base for LMR components with PNC; development and testing of an advanced double wall tube steam generator with the Japan Atomic Power Company (JAPC), using testing facilities at ETEC; development of LMR reprocessing technology with PNC using facilities at ORNL; the development with the Japan Atomic Energy Research Institute (JAERI) of a HTGR fuel performance testing program, utilizing facilities at ORNL; and MHTGR design-related activities with Siemens/INTERATOM (Wrst Germany). The estimated costs of these tasks are targeted to be shared approximately equally with foreign partners. Foreign funding

Answer 5
(continued): is approximately $16.1 million in FY 1988 and estimated to be about $11.5 million in FY 1989.

In addition, design and technology collaboration efforts are underway between U.S. LMR designers and their Japanese counterparts under a DOE-supported private sector initiative. Areas of exchange include component development, reactor core evaluation and development, shutdown cooling system development, and related advanced reactor design studies and evaluations. The cost of this initiative is targeted to be shared equally by U.S. and foreign partners at approximately $1.2 million per year.

DOE also has an agreement in place with PNC to exchange design and technology information from the terminated Clinch River Breeder Reactor project and the Japanese MONJU project (now under construction). Under this agreement, DOE currently has two representatives assigned to the MONJU project in Japan to obtain data as they are developed.

QUESTIONS FROM CHAIRMAN MARILYN LLOYD

Question 6: How does the DOE manage the money that the Congress appropriates every year for the HTGR, i.e., what is the management system?

Answer: The system used to manage the Department of Energy (DOE) Modular High Temperature Gas Reactor (MHTGR) program activities and funding is a variation of the Performance Measurement System (PMS) which has been successfully applied to a wide range of technology programs. The program has been subdivided into work elements under a Work Breakdown Structure. Progress, milestones, and costs for each element are tracked by a reporting system that meets the Cost and Schedule Control System Criteria (CSCSC) of the Department. Comprehensive program reviews are conducted by senior DOE program managers to assess overall program progress. Timely corrective action is initiated when required. This system, along with the nearly daily interaction between the contracting office program personnel and the contractors, has proven to be an effective management approach.

QUESTIONS FROM CHAIRMAN MARILYN LLOYD

Question 7: To demonstrate their commitment, the Gas Cooled Reactor Associates and the MHTGR program participants have recommended a threshold of non-DOE financial support for a lead plant project before DOE funding would be made available. What do you think of this recommendation?

Answer: We believe that the recommendation put forth by the Gas Cooled Reactor Associates and the Modular High Temperature Gas Reactor (MHTGR) program participants could eventually provide a possible basis for cooperative Federal/private sector funding of a demonstration project. However, to consider building one now would be premature. Several key licensing and technology questions should be answered satisfactorily before either the Department or the private sector makes a commitment to proceed with a new construction project.

QUESTIONS FROM CHAIRMAN MARILYN LLOYD

Question 8: If you were to continue the MHTGR program consistent with last year's Congressional direction, how much money would be required?

Answer: If the FY 1988 tasks were continued into FY 1989, approximately $35 million would be required. However, the Department believes that it is prudent to await the results of the current NRC licensing review and subsequent definition and resolution of issues before proceeding with a higher level of R&D funding than that requested for FY 1989.

QUESTIONS FROM CHAIRMAN MARILYN LLOYD

Question 9:	How should we interpret the 18% reduction from FY 88 to 89 requests in the framework of the Department's commitment to advanced reactor R&D?
Answer:	The Department's commitment to pursue advanced reactor technologies with the potential for significant breakthroughs in economics, safety, licensability and waste management options has not diminished. The current program emphasizes definition and confirmation of work focussed on achieving needed technical breakthroughs and defers, in large part, design-specific technical support activities. This results in a reduced overall civilian reactor development budget.

QUESTIONS FROM CHAIRMAN MARILYN LLOYD

Question 10: Please provide the breakdown of facility operating costs at the three major facilities associated with the Advanced Reactor Research and Development program including the Energy Technology Engineering Center (ETEC), Westinghouse Hanford (WHC), and the Argonne National Laboratory-West (ANL-W) facilities?

Answer: The FY 1989 costs for sustaining the operation of these sites and for performing the capital funded activities are presented below. It should be noted that $15.0 million of the total required funding is to be provided by the Space and Defense Power Systems Program ($5.5 million for WHC, $8.5 million for ANL-W, and $1.0 million for ETEC) for facilities irradiation and test charges.

FY 1989 FACILITY OPERATING COSTS

(BA in Millions)

	WHC	ANL-W	ETEC
Facilities			
Operating	$48.7	$35.7	$ 9.0
Capital Equipment	0.8	3.5	0.3
Construction	3.5	4.5	1.2
Subtotal	$53.0	$43.7	$10.5
Space and Defense Power Systems			
Operating	5.5	8.5	1.0
Total	$58.5	$52.2	$11.5

QUESTIONS FROM CHAIRMAN MARILYN LLOYD

Question 11: What is the level of international participation in projects at the Advanced Reactor Research and Development facilities? Are the international programs performed through cooperative arrangements which involve in-kind support from the users or are there direct operating funds provided by foreign participants to these facilities?

Answer: The level of international participation in projects at DOE nuclear test facilities under the cognizance of the DOE Office of Nuclear Energy is estimated to be approximately $6 million in FY 1989. In addition, there are international agreements under the cognizance of the DOE Office of Energy Research with Japan and with International Energy Agency (IEA) partners for collaborative materials research, utilizing a Materials Open Test Assembly in the Fast Flux Test Facility. The cost of hardware, facility operations, and research in the Office of Energy Research-sponsored program includes fully shared funding with foreign contributions of about $2.5 million in FY 1989.

Agreements with the Swiss, PNC, Japan and United Kingdom Atomic Energy Authority involve in-kind support and do not provide direct operating funds for the DOE facilities utilized in these programs. Direct operating funds are provided by the foreign participants of the joint Operational Reliability Testing (ORT) and Double Wall Tube Steam Generator (DWTSG) programs for the involved test facilities

Answer 11 (continued): services and related test activities. The FY 1989 budget request for Facilities takes into account the projected funds to be provided by the ORT and DWTSG foreign participants and by the DOE Office of Energy Research.

QUESTIONS FROM CHAIRMAN MARILYN LLOYD

Question 12:	Please explain, with an example, how the safety program functions within the SP-100 program, i.e., how are safety considerations impacting reactor and power system designs?
Answer:	The safety program is an integral part of the overall SP-100 program and has the highest priority. It involves both the line managers who are charged with the overall safety responsibility and a broad spectrum of safety review groups to conduct independent analyses of designs and ongoing safety work and to provide independent safety assessments and advice. For example, three of the safety review functions involve a Safety Advisory Committee (made up of experts from government and industry) that provide advice to the Project Manager, an Independent Safety Assessment Group that advises the government Program Manager, independent safety review groups within the industrial system developer. As the program evolves towards an actual flight, it will also be formally reviewed by the established Interagency Nuclear Safety Review Panel (INSRP). Within the project, the safety groups help define potential accident conditions, analyze the potential range of effects to the system, and then work with the subsystem designers to incorporate the necessary safety features. The safety groups also work closely with the reliability group to ensure that

Answer 12 (continued): the safety features meet stringent reliability requirements. Both the system contractor and the project office audit team review the design to ensure it meets the safety technical specifications.

Safety is integrated within the entire SP-100 design philosophy to ensure a system capable of meeting the designed levels of public safety, health protection, environmental protection, and special nuclear material protection.

QUESTIONS FROM CHAIRMAN MARILYN LLOYD

Question 13: Does the advanced reactor R&D program include support for involvement of universities in advanced nuclear energy R&D? If yes, do you coordinate such activities with the Congressionally initiated program to support nuclear engineering departments that was funded within the Office of Energy Research Programs?

Answer: In FY 1989, support for universities planned by the Office of Nuclear Energy in the advanced reactor R&D program will take the form of continuing 20 graduate student fellowships in Nuclear Engineering and Health Physics and initiating a program with universities to use the unique resources offered by the EBR-II facilities complex for the training of students in all aspects of nuclear energy.

The Office of Nuclear Energy has coordinated its financial support of university-sponsored nuclear engineering programs with the Office of Energy Research.

QUESTIONS FROM CHAIRMAN MARILYN LLOYD

Question 14: You testified that the Department has made the decision to develop core designs based upon the metal fuel concept rather than oxide fuel concept. What are the goals and objectives of the oxide fuel development activities performed under agreements with Japan? How are these activities impacted by this decision? Is Japan expressing interest in the metal fuel concept? Should the existing cooperative arrangements with Japan be changed to focus on metal fuel? Has the Department's decision to emphasize the metal fuel program over the oxide fuel program undergone peer review?

Answer: The goals and objectives of oxide fuel development activities performed under agreement with Japan are to maintain awareness of improvements in oxide fuel technology through access to Japanese program data with minimal cost to DOE. The existing oxide fuel agreements are not impacted by the DOE decision to emphasize the metal fuel concept.

Japanese interest in the metal fuel concept has greatly increased with each successful technical achievement in the DOE Integral Fast Reactor (IFR) program. We believe, however, that existing cooperative arrangements with Japan should not be changed to focus on metal fuel development. Potential new agreements that focus on metal fuel are currently being pursued that would be of mutual benefit to DOE and Japan.

Answer 14
(continued):

DOE's decision to give priority support to the development of the metal fuel cycle program was made only after extensive technical reviews had clearly established the potential benefits to be gained. In April 1986, DOE established a task force to review the current status of both oxide and metal fuels and to determine the future potential of each of these fuels in the development of liquid metal reactors. Experts from DOE Headquarters and national laboratory field offices were members of this review group. In August 1986, the task force recommended support for the development of the metal fuel cycle program. In October 1986, the Energy Research Advisory Board also recommended that DOE continue its emphasis on metal fuel cycle development. Each of these reviews were independent and made by recognized experts in nuclear energy and related scientific disciplines. Additionally, there is an extensive, on-going peer review of the IFR concept established by the University of Chicago at the request of DOE's Chicago Operations Office. The Department carefully considers results from these peer reviews.

QUESTIONS FROM CHAIRMAN MARILYN LLOYD

Question 15: At what level is Space Nuclear participating with the mission agencies to define a flight demonstration system for the SP-100 Space Reactor?

Answer: The SP-100 Program is closely coordinated with the NASA mission planners, the SDIO, the Director of Space and SDI Programs for the Air Force, Air Force Systems Command, Space Division System Project Offices (SPO's) and their contractors. A joint effort has begun with NASA, the SDIO, and the Air Force to launch a Nuclear Electric Propulsion (NEP) flight experiment as the first flight mission for the SP-100. This mission will enable other NEP missions as well as prove the reactor technology in space.

QUESTIONS FROM CHAIRMAN MARILYN LLOYD

Question 16: While we support the Department's program on space and defense power programs, we are, nevertheless, concerned that perhaps the civilian program is paying too large a share of the cost of developing such systems for the Department of Defense. Please comment. Additionally, please identify the Department's contributions to the development of nuclear power systems specifically designed for defense applications?

Answer: All projects within Space and Defense Power Systems are conducted and jointly funded with DOD and/or civilian user agencies. All of these projects potentially have both defense and civilian applications. None are for solely defense applications. Cost sharing arrangements are agreed to by all participating agencies in a Memorandum of Understanding or a Memorandum of Agreement. In most cases the user has or will fund over 50 percent of the project cost for research, development and demonstration activities, with a greater portion of the costs for production units being the responsibility of the user organization. As part of its overall charter to carry out nuclear energy development in support of other Federal agencies, DOE is responsible for a larger portion of the funding for nuclear technology development, safety, preparation and utilization of test and assembly facilities and other key functions. The user agencies provide funding for overall system design, power conversion technology, and actual flight hardware.

Answer 16
(continued): The President's budget request appropriately reflects this division of responsibility.

QUESTIONS FROM CHAIRMAN MARILYN LLOYD

Question 17: Why are Office of Nuclear Energy Program funds being applied to a space power program directed specifically to national security application--a classified mission called Centaurus? Shouldn't such activities be solely supported with Defense Program funding?

Answer: The Department's funding request for Centaurus is based on the reactor technology development role assigned to DOE. This funding is being used to evaluate energy transfer processes which are of broader interest than just for the DOD. If the current evaluation is favorable, DOD would bear the dominant portion of any future cost of actually developing and producing a unit for application. The Office of Nuclear Energy funding for Centaurus is approximately 30 percent (in FY 1989) of the current funding. Funding by the Office of Nuclear Energy should continue at the proposed level.

QUESTIONS FROM CHAIRMAN MARILYN LLOYD

Question 18: At the Subcommittee's request, the GAO is preparing a report on potential technology transfer opportunities for which technologies developed in the Space and Defense Power Programs can find application in the terrestrial advanced reactor program. Based upon their preliminary findings, there appears to be several such opportunities. Is the Department intending to implement such transfer programs?

Answer: While we do not yet have the GAO preliminary findings, we are aware of several areas where the transfer of technology potentially could be of benefit. It is the policy of the Department to pursue such technology transfer opportunities. As technology is developed in our programs, we will evaluate the specific transfer potential and take any appropriate implementing actions.

QUESTIONS FROM CHAIRMAN MARILYN LLOYD

Question 19: You have six on-going projects in food irradiation which have an expected Federal funding need of $5 million in fiscal year 1989? Why did you request no funding for this activity in midstream?

Answer: The Department could not justify a budget request for this program in view of the fiscal constraints in the overall budget.

QUESTIONS FROM CHAIRMAN MARILYN LLOYD

Question 20:	Can you provide a chart showing the schedule and funding for each irradiator project?
Answer:	The schedule and total estimated cost, assuming work continued to the completion date, for each food irradiator project is shown below.

State/Project Sponsor	Date of Facility Operations	Total Estimated Funding Required (S Millions)
Oklahoma--RedArk Development Authority	1991	6.7
Iowa--Iowa State University	1989	6.2
Florida--Department of Agriculture & Consumer Services	1989	6.3
Hawaii--Department of Planning & Economic Development	1992	6.2
Washington--Port of Pasco	1994	6.4
Alaska--University of Alaska	1995	6.6

QUESTIONS FROM CHAIRMAN MARILYN LLOYD

Question 21: How much money are the participants in the irradiator projects providing under the cooperative agreements?

Answer: No specific dollar amounts were identified as the project sponsors' contributions in the cooperative agreements. The table below shows the estimated sponsor contributions to date. In addition, each sponsor has agreed to provide ancillary research and support resources for their project.

Project	Estimated Sponsor Contribution
Oklahoma--RedArk Development Authority	Undefined
Iowa--Iowa State University	$2 million
Florida--Department of Agriculture & Consumer Services	$0.4 million
Hawaii--Department of Planning & Economic Development	$1.5 million
Washington--Port of Pasco	$2.8 million
Alaska--University of Alaska	Undefined

QUESTIONS FROM CHAIRMAN MARILYN LLOYD

Question 22: It is my understanding that the SP-100 program was funded by the government prior to the time that its applications were recognized for the SDI program. Could you tell me when the SP-100 program was initiated, which service or agency was responsible for it, and what levels of funding it has received through fiscal year 1986?

Answer: The initial efforts to select a space reactor technology for development began in 1982. The space reactor program was structured as a triagency effort in 1983 with the Defense Advanced Research Projects Agency as the responsible organization within the Department of Defense prior to the involvement of the Strategic Defense Initiative Organization in 1984. The other two participating agencies and signatories to the Memorandum of Agreement were, and continue to be, the Department of Energy and the National Aeronautics and Space Administration. From 1982 through FY 1986, the total amount of DOE funds appropriated for the SP-100 program was $37.4 million.

QUESTIONS FROM THE MINORITY

Light Water Reactor (LWR) Program

Question 1: The Light Water Reactor program has plans for demonstrating the certification of large advanced LWR's by 1991. If the plant design can be certified by the Nuclear Regulatory Commission, the licensing time for new plants would be shortened. Has any utility company shown interest in ordering a large size plant for the future?

Answer: The utilities have generally shown strong interest and support for the ALWR program through their support of the Electric Power Research Institute ALWR program and their participation in a Utility Advanced Light Water Reactor Steering Committee. The ALWR designs being certified (licensed) are consistent with the needs of the utilities as expressed in their ALWR Requirements Document.

Establishing the certification process for standard nuclear plant designs will produce much greater confidence by the utilities in making the decision to acquire these plants. The risks associated with delayed plant construction or cancellation due to licensing or regulatory problems that have characterized the current generation of LWR's will be greatly diminished because of the availability of "pre-licensed" designs.

It is correct, however, to say that utilities are not yet ready to commit to any nuclear plant (regardless of size).

Answer 1
(continued):

pending the outcome of these current certification activities. The availability of certified plant designs in 1991 and beyond will be a key factor in making nuclear power a viable option when decisions are made by individual utilities for meeting projected load growth and replacement capacity requirements beginning in the 1990's.

QUESTIONS FROM THE MINORITY

Light Water Reactor (LWR) Program

Question 2: Both the large and mid-size LWR's have their advantages. In your opinion, what does the utility prefer--a certified large-size LWR, or a mid-size LWR incorporating passive safety features?

Answer: In our opinion, both. There are a variety of needs among the many electric utilities in the United States, depending on factors such as the regional load growth, financial capability of the utilities, and institutional or regulatory constraints. The preference of the individual utilities will vary according to their specific circumstances.

The larger Advanced LWR plants, which will be available earlier in a "certified standard design" condition, could meet regional load growth requirements for large utilities in an economic manner. The mid-size Advanced LWR, in addition to innovations that allow safety to be achieved by more passive means, offers a better match with the capacity expansion plans and capital formation capabilities of other utilities.

Independent of plant size, utilities will demand an improved, licensed product exhibiting enhanced safety and reliability, improved performance, and good economics. These qualities are available in large and mid-size designs, although the

Answer 2 (continued): mid-size designs are several years behind the large plants in demonstrating that they satisfy these conditions.

QUESTIONS FROM THE MINORITY

Light Water Reactor (LWR) Program

Question 3: The DOE is also developing the technology for extending the licensed life of reactors, while there seems to be no criteria for plant life extension by the NRC at this time. How would this technology be useful?

Answer: The Department is supporting work directed toward extending the licensed life of U.S. power reactors. This work is being accomplished through a cooperative effort involving DOE, the NRC, and several industry organizations.

The NRC has developed a schedule for establishing the regulatory policy, process, and criteria for license renewal; the technology being developed in the cooperative plant-life extension program will provide the basis for these NRC actions. As currently planned, lead utility plant(s) will be identified in 1988 and a license renewal application will be submitted by the end of 1991.

This program, if successful, offers the Nation substantial benefits. The potential savings to consumers could amount to $200 billion dollars or more. In addition, lifetime extension of currently operating LWR's will reduce the need for electric generating capacity around the turn of the century.

QUESTIONS FROM THE MINORITY

Light Water Reactor (LWR) Program

Question 4: The TMI program is being completed this year. Results of this program will be useful for the safe operation of nuclear plants. Is there any benefit to the public regarding attitude toward nuclear power?

Answer: The TMI program has provided and continues to provide useful information for the safe operation of nuclear plants, both here and abroad. The benefits related to public attitudes occur by the increasing awareness of the significant capability of current plants to cope with severe accidents without endangering public health and safety and of the ability to conduct accident clean-up operations in a manner which ensures the health and safety of the public and of the workers involved in the clean-up.

QUESTIONS FROM THE MINORITY

Advanced Reactor R&D

Question 5: The DOE is giving priority support to the development of the IFR (Integral Fast Reactor) concept with metal fuel, whereas the Japanese still believe in oxide fuel. Why do you pursue a cooperative program with them?

Answer: We pursue the cooperative program with Japan because it permits us to exchange information which will benefit both countries. If the IFR demonstrates the potential that it may have, the Japanese may reconsider their choice of technology for a breeder reactor; if not, the oxide data will be available for use by the U.S. and Japan.

QUESTIONS FROM THE MINORITY

Question 6: The IFR concept also holds the promise of burning high-level waste from the Nation's LWRs. Is the pyroprocess in this concept compatible with LWR fuels?

Answer: The pyroprocess under development for the Integral Fast Reactor (IFR) metal fuel cycle is not directly compatible with light water reactor (LWR) fuels. In order to burn LWR spent fuel in a metallic-fueled Liquid Metal Reactor, it is necessary to add intermediate processing which will efficiently reduce the LWR oxide fuel into a metallic form that is directly compatible with the IFR pyroprocessing technology.

QUESTIONS FROM THE MINORITY

Question 7: With the promising technology breakthroughs that would simplify nuclear waste management, is there still a need for a high-level waste repository?

Answer: Yes. The development of LMR technology related to waste management options is in the embryonic stage of development. At best, its practical application would be well after the turn of the century. Hence, geologic repositories for high-level nuclear waste are definitely necessary.

QUESTIONS FROM THE MINORITY

Question 8: The Europeans seem to think the age of Liquid Metal Reactor won't come until mid to late next century. What is your prediction for both the Liquid Metal Reactor and the HTGR?

Answer: The energy resource posture of European nations is significantly different than that of the United States. Hence, their decisions and projections are driven by different circumstances than ours. The needs of the marketplace and the availability of proven technology will determine when and if new reactor technologies will be selected for introduction commercially in the U.S. Our programs are paced to enable market forces to consider these advanced technologies around the turn of the century.

QUESTIONS FROM THE MINORITY

Space/Defense Power Systems, Advanced Nuclear Systems (RTG)

Question 9: During FY 1988, the schedule of the SP-100 program slipped for 6 months. What does the schedule look like for FY 1989? Is the funding requested enough to maintain a viable program?

Answer: The schedule of the SP-100 program is directly related to appropriated funding. With the reduced FY 1988 appropriation, the FY 1989 funding requests by DOE, DOD, and NASA can maintain the current SP-100 schedule of completion in FY 1992, though with increased total costs. If the full amount of funds requested for FY 1989 is not appropriated, the SP-100 schedule or program content will be detrimentally impacted.

QUESTIONS FROM THE MINORITY

Question 10: The SP-100 design has incorporated safety features such as a core cooling system (bayonet tube) in case of a loss-of-coolant accident. Does the DOE have plans for safety tests? Have launching accidents been considered?

Answer: Safety tests will be done to validate the technology used in the SP-100 reactor Loss-of-Coolant Accident (LOCA) loop. The tests will range from material characterizations to the incorporation of the full-scale LOCA loop in the reactor ground test. The LOCA loop, i.e., the bayonet design, is flexible enough to allow design changes for the flight system if the engineering results show that less or more heat removal capability is required.

An important point to consider when evaluating SP-100 safety is the fact that the reactor will not be operated until it reaches a stable orbit. Also to insure that the SP-100 can satisfy all its safety objectives. the design will be verified through analyses, computer modeling, and testing. Specific safety tests are planned to assess reactor response to launch and ascent accident scenarios, i.e., launch pad fire, launch abort, and re-entry. The design is measured against a set of safety technical specifications which must be met by the system contractor. To ensure the safety specifications are met there are a number of program and independent safety review committees which review the design and the analyses.

QUESTIONS FROM THE MINORITY

Question 11: What would the DOE consider as the best timing for a flight demonstration of the SP-100 system?

Answer: Present DOE planning, as coordinated with NASA, the SDIO, and the Air Force, calls for a flight experiment for a Nuclear-Electric Propulsion assembly using an SP-100 reactor to occur in the mid 1990's. This timing is consistent with the GES SP-100 Nuclear Assembly Test. Planning and initial development efforts for the flight experiment will proceed in parallel with the Nuclear Assembly Test in order to meet a mid-1990's launch.

QUESTIONS FROM THE MINORITY

Question 12: Did the lesson learned from the Challenger accident provide any insight into the preparation of RTGs for the upcoming NASA missions (Galileo and Ulysses)?

Answer: The Challenger accident did provide insights into the preparations for the launches of Galileo and Ulysses. From the accident it was learned that the liquid hydrogen and liquid oxygen reacted to produce pressure forces that were well below the tested and proven containment capability of the radioisotope thermoelectric generators (RTGs). The Challenger accident and a subsequent Titan 34D launch vehicle accident showed the potential for ruptures of the solid rocket boosters (SRBs) which, in turn, could mean the potential for an impact of the SRB case on the RTGs. Tests and analyses are being conducted on this new accident scenario. To date, the results are good in that they show the RTGs will contain the fuel for the more likely accident environments.

QUESTIONS FROM THE MINORITY

Facilities

Question 13: Would you please describe what you see as the major missions for the EBR-II in Idaho, ETEC in California, and FFTF in Washington?

Answer: EBR-II: Operate the EBR-II complex as a prototype Integral Fast Reactor system. Particular emphasis at EBR-II is placed on conducting irradiation experiments to qualify fuels and materials for the Advanced Reactor R&D and Space and Defense Power Systems programs, and performing reactor power plant safety tests to demonstrate the potential for further enhancements in passive safety capabilities of liquid metal reactors.

ETEC: Perform liquid metal steam generator testing at the Sodium Components Test Installation, including testing of the Double Wall Tube Steam Generator under a cooperative agreement with the Japan Atomic Power Company. At other ETEC facilities, perform additional non-nuclear testing activities including seismic tests for the Advanced Reactor R&D program and component tests in support of the Space and Defense Power Systems program.

Answer 13
(continued):

FFTF: Conduct prototype fuels and materials irradiations in support of DOE's nuclear fission (Advanced Reactor R&D and Space and Defense Power Systems) and fusion energy R&D programs. DOE is studying the feasibility of using the FFTF complex for additional missions.

QUESTIONS FROM THE MINORITY

Facilities

Question 14(a): Over the past 10 years, the staffing level at EBR-II was lowered by 25 percent, FFTF was lowered by 36 percent, and ETEC was lowered by 65 percent. Maybe one reason is that these facilities have more experienced staff now compared to 10 years ago. Can safety and effectiveness still be assured?

Answer: Yes. The staffing levels at these facilities have been reduced substantially; high-quality personnel must be available and provided with adequate resources to assure continued safe and secured operations of the facilities while carrying out the technical programs required.

QUESTIONS FROM THE MINORITY

Facilities

Question 14(b): At the funding level the DOE requested for fiscal year 1989, can we still conduct viable programs at these facilities?

Answer: The funding level requested for FY 1989 does not provide for the conduct of LMFBR research and development programs (which formed the basic mission of the FFTF when its construction was authorized); however, the Department has been utilizing the FFTF in support of other priority programs. Funding for ETEC is also substantially reduced to reflect a reduced mission for that facility (LMFBR steam generator testing). The present funding for the EBR-II complex will allow the orderly completion of the IFR demonstration program.

QUESTIONS FROM THE MINORITY

Facilities

Question 14(c): What is the Department of Energy's funding projection for the next 5 years - about the same level, or a lower level?

Answer: DOE's funding projection for the next 5 years increases slightly due principally to escalation. The projection includes funding that will be contained in the Space and Defense Power Systems outyear funding projection for facility irradiations and test services.

QUESTIONS FROM THE MINORITY

Facilities

Question 14(d): If the budget continues to shrink so that one of the facilities has to be shutdown, can the remaining facilities take on all the programs?

Answer: At this time, the operational facilities at all three sites are essential to achieve planned program requirements. We will continue to evaluate the utilization of our facilities and perform further consolidations as appropriate to be consistent with program requirements and funding availability.

QUESTIONS FROM THE MINORITY

Remedial Actions and Waste Technology

Question 15: One of the objectives of the byproducts utilization program is to explore beneficial uses of nuclear byproducts. What isotopes are being considered by the Department?

Answer: The DOE byproducts utilization program is directed primarily toward the application of irradiation technology for treatment of foods and the development of radioluminescent lighting systems. Food irradiation can be accomplished using a machine to generate high-energy electrons or X-rays or using gamma radiation from certain isotopes, usually cobalt-60 and cesium-137. Each of the six regional food irradiation project sponsors has the option to select the radiation source that is the most suitable to their needs.

Relative to the development of radioluminescent lighting systems, an isotope of hydrogen--tritium--is being used. The use of other radioactive isotopes for lighting system applications would be considered for special applications.

QUESTIONS FROM THE MINORITY

Remedial Actions and Waste Technology

Question 16: The radioluminescent lights developed under the byproducts utilization program seem to have good potential for civilian as well as military use. What is the status of this program, and is the DOE seeking civilian or military cosponsors?

Answer: As directed by the Congress, DOE continued research and development of radioluminescent lighting systems with a successful test of a runway lighting system for the U.S. Air Force and the development of a civilian runway lighting system for remote communities in Alaska. In January 1988, a workshop was conducted to identify the most promising areas for future research. The workshop results suggested that significant improvements can be made in brightness and adaptability of radioluminescent lights by developing a solid-state version of the tritium light. Research efforts based on these concepts have been initiated. Civilian and defense agencies have been contacted regarding their participation in the program. There are a number of potentially beneficial applications in military systems such as lighting for emergency egress from ships and temporary landing pads or runways. DOE is continuing its joint efforts with the State of Alaska for remote airfield lighting systems and to cooperate with the State of Florida for marine signage applications.

Mrs. LLOYD. And our next witness is Mr. Gregory Reck from NASA's Office of Aeronautics and Space Technology. He is the Director of the Propulsion Office. We welcome you, Mr. Reck. Your written statement will be made a part of the record, and you do have a very fine and detailed statement. It will be a part of the record and you may summarize as you wish.

STATEMENT OF GREGORY M. RECK, DIRECTOR, PROPULSION, POWER AND ENERGY DIVISION, OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, WASHINGTON, DC

Mr. RECK. Thank you, Madam Chairman.

I do appreciate the opportunity to talk with you this afternoon regarding the SP-100 nuclear reactor power system that NASA is jointly sponsoring with the Department of Energy in the Strategic Defense Initiative Organization. From NASA's perspective, the reactor technology being developed in the SP-100 program, coupled with more efficient power conversion technology, can enable the high-capacity, long-life power systems needed for future civil space missions.

The President's new national space policy, to ensure U.S. leadership in space, established a long-range goal for the United States of expanding human presence and activities beyond earth orbit into the solar system. NASA's strategic planning activities, led earlier by Dr. Sally Ride, have been characterized by an aggressive long-term view which includes several space exploration options.

In support of these future space ventures, NASA's fiscal year 1989 budget request includes $100 million for starting a Pathfinder Program of detailed studies and focused technology development efforts to provide a sound basis for future decisions on potential new missions of space exploration.

I want to briefly describe some aspects of those potential missions which have a significant influence on our high-capacity nuclear power technology planning. Then I'll discuss NASA's increasing role in support of the SP-100 Ground Engineering System, and some notable accomplishments in our ongoing conversion technology activities.

NASA has formed the Office of Exploration to direct the agency-wide planning activities which are addressing the new mission opportunities. The initial planning efforts have identified a number of activities which may require power sources with capacities and duty cycles beyond today's capabilities.

We believe that space nuclear reactor power is vital to accomplishing these missions. For example, nuclear power is attractive for long-duration surface operations at sites with extended night periods. Advanced photovoltaic systems can be used to support these missions, but an energy storage system would be required to provide electrical power through the night cycle.

If the power requirements of the surface operations are sizable and the night cycle is long, the storage requirements can be very large, and even with advanced technology regenerative fuel cells, the storage system becomes the dominant factor in the total mass of the power system.

A nuclear power system does not require this large storage system and the resulting weight savings provides a compelling argument for nuclear power. The importance of the weight savings is magnified when considered in terms of the much greater savings in mass that must be delivered to low-Earth orbit.

Nuclear power systems may also be necessary for operations at locations well beyond earth orbit, where solar intensity is much lower or where local environmental conditions, such as dust, may reduce the performance over the life of photovoltaic systems.

Another application of great interest to mission planners is the use of electric propulsion for interplanetary transportation. This form of propulsion is very efficient. It requires a very-high-capacity, light-weight power system.

In addition to the manned-exploration missions, we've continued our studies of a broad spectrum of other potential civil missions where nuclear power systems might be applicable. These include operations in earth orbit, in the inner solar system and to the outer planets and beyond.

For example, we study the feasibility of using a small nuclear reactor power system in the range of 1 to 50 kilowatts of electricity on a candidate planetary spacecraft which could be used to study the outer planets. We found that the nuclear system could be integrated into the spacecraft to power the spacecraft and it would provide enough additional power to use electric propulsion instead of chemical.

If chemical propulsion is used, the mission will require gravity-assist maneuvers around planets which impose launch-window constraints. The use of electric propulsion could relax those constraints by providing a direct trajectory, and also enhance the science return from the mission.

From our studies, NASA has determined that a nuclear reactor power system is a prime candidate for supplying large amounts of power for extended periods of time in space environments. NASA's current space technology programs, as represented by the Civil Space Technology Initiative, CSTI, and the proposed Pathfinder Program, are stepping up to the challenges presented by future civil space ventures.

NASA has been providing technical support to the Ground Engineering System program since its inception. In fiscal 1988, NASA is, for the first time, providing $10 million of direct funding support to the SP-100 GES Program, and in fiscal 1989 we've proposed that $30 million of the Pathfinder Program be used to support the GES activity.

The reactor technology developments being validated in the SP-100 GES program are the essential first step. However, to support the high-powered demand missions, we need to develop a more efficient system for converting the SP-100 reactor thermal energy to electric energy, or electric power.

As part of the CSTI, we've incorporated and expanded our ongoing activities to provide this advanced conversion technology. Our goal is to provide at least a five-fold increase in the electric power that can be produced from a thermal output of the SP-100 reactor, and at the same time, more than double the system's power-to-weight ratio.

A significant part of this improvement will result from the use of a high-efficiency, Stirling dynamic energy conversion system in place of the static thermoelectric system that's planned for the GES. We've completed testing of a lower-temperature configuration of the Stirling engine. The engine produced 90 percent of the predicted 25 kilowatts of power and operated at 22 percent efficiency. And in fiscal 1988, we've initiated a full-scale, superalloy Stirling engine which will operate at higher temperatures, above 1,000 Kelvin, and ultimately, these tests will enable the development of an engine operating at the 1,300 Kelvin produced by the SP–100 GES reactor. These increases in temperature enable improvements in efficiency without large increases in the radiator size or weight.

The supporting high-temperature materials and structures technology effort is also underway. A refractoring metal, PWC–11, has been established with superior characteristics to the Nb–1Zr alloy which is a baseline material for the GES program, and the improved high-temperatures properties of this material have been demonstrated even after prolonged exposure to high temperatures.

In addition to the work on dynamic conversion systems, we're providing direct support to the GES effort through the development of higher-efficiency thermoelectric materials. Changes in the composition and processing of the baseline silicon-germanium thermoelectric material have resulted in improved conversion efficiencies and we anticipate further gains.

In summary, we consider nuclear power an essential element of NASA's planning and an integral part of the proposed Pathfinder Program. The potential future surface operations envisioned in Pathfinder will be dependent on high-capacity power, and our support of the SP–100 Program is a result of those potential mission needs.

The Pathfinder Program is a small percentage of the NASA budget and, we believe, a good investment. The technologies it would provide, such as the SP–100 power system, will have many other applications.

And finally, we believe it's urgent to move quickly. The President's space policy has sent a message and Pathfinder is a part of that message. I urge your support of the Pathfinder Program, of which SP–100 is an integral part. We've identified substantial benefits resulting from the use of nuclear power and are aggressively supporting those activities to make high-capacity, space nuclear power a safe and technically viable option for civil missions.

Thank you very much, Madam Chairman.

[The prepared statement of Mr. Reck follows:]

Hold for release until
presented by witness
March 16, 1988

Statement
of
Gregory M. Reck
Director, Propulsion, Power and Energy Division
Office of Aeronautics and Space Technology

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

before the

Subcommittee on Energy Research and Development
Committee on Science, Space, and Technology
House of Representatives

Madam Chairman and Members of the Subcommittee:

I appreciate this opportunity to convey to this Subcommittee NASA's firm commitment to ensuring timely development and utilization of space nuclear reactor power technology. The space reactor technology to be validated in the SP-100 Ground Engineering System (GES) Program, coupled with the advanced power conversion technology developments being performed by NASA, can enable the development of the higher power, long-life space nuclear reactor power systems that are needed to support future civil space missions.

The President's new National Space Policy to ensure U.S. leadership in space establishes that, for the first time, the United States has a long-range goal of expanding human presence and activities beyond Earth orbit into the solar system. This has historic significance and will serve to guide civil space activities well into the next century. NASA's strategic planning activities led by Dr. Sally Ride were characterized by an aggressive, long-term view for U.S. space ventures in the 21st Century (Leadership and America's Future in Space, A Report to the Administrator, August 1987). This report included civil mission options to expand human presence beyond Earth and to advance the scientific knowledge of the solar system. In support of future space ventures, NASA's FY 1989 budget request includes $100 million for starting the Pathfinder program, a program of detailed studies and focused technology development efforts that are to provide a sound basis for future decisions on approaches and missions. I will address the aspects of these mission objectives which are pertinent to our high capacity nuclear power technology development program planning. Then, I will discuss NASA's increasing role in support of the SP-100 GES program and accomplishments of our ongoing advanced power conversion technology endeavors.

NASA has formed the Office of Exploration to direct the agencywide program planning activities addressing new mission opportunities. The initial planning efforts have identified a number of activities which may require power sources with capacities and duty cycles far exceeding that practical with today's technology. New design and operational concepts are needed. NASA's current space technology programs, as represented by the Civil Space Technology Initiative (CSTI) and the proposed Pathfinder program, is stepping up to the challenges presented by future civil space ventures.

We believe that space nuclear reactor power is vital to successful implementation of future space ventures. For example, nuclear power is attractive for long-duration surface operations at sites with extended night periods. Advanced photovoltaic systems could be used, but an energy storage system would be required to provide electrical power through the night cycle. Even with the most advanced technology, this storage requirement is the major factor in power system weight. A nuclear power system does not require energy storage. The weight savings resulting from not having an energy storage system provides a compelling argument for nuclear power. The importance of this system weight reduction is magnified when considered in terms of the even greater reduction in mass that must be delivered to low Earth orbit. In addition, the lower solar insolation conditions at locations further from the sun and the effects of the local surface environment, such as dust, serve to reduce the performance and the life of photovoltaic systems.

Another application of interest to the mission planners is the use of a high specific power nuclear source coupled with a high performance electric propulsion system for potential future interplanetary transfer vehicles. The application of nuclear-electric propulsion systems could enable more cost-effective commercial ventures and scientific exploration of the solar system. In addition, we have continued our investigations of a broad spectrum of potential civil missions that could be enhanced or enabled by the application of compact, long-life, high performance nuclear power systems (Figure 1). Recently, the feasibility of using a reactor power system for a candidate planetary mission was examined. This study indicated that the reactor could both power the spacecraft and provide the power for an electric propulsion system (Figure 2). The results established the potential advantages in terms of enhanced mission performance and science return. We believe that once space nuclear power operations have been demonstrated and accepted by mission planners, the potential for much broader applications will emerge.

Because of the requirements envisioned for supplying large amounts of power for extended periods of time, development of this enabling technology base is considered essential. NASA has been providing technical support to the GES program since its inception. This support has been in areas of technical management and oversight, space subsystem development, system engineering, and materials and test evaluations. In FY 1988, NASA is, for the first time, providing $10 million direct funding support to the SP-100 GES program. In FY 1989, the NASA share will grow to $30 million funded from the Pathfinder program. The total R&D outlay by NASA for the GES over the course of the program is estimated to be $135 million.

With any nuclear system, safety is of primary importance. As a result, safety is an integral part of the SP-100 GES development and validation. The safe operation of the reactor power system will be ensured for normal and off-normal conditions of ground operations, launch, on-orbit and end-of-life disposal.

The ability to provide nuclear power for high power demand activities such as surface operations is best fulfilled by utilizing the high temperature reactor technology being developed in the GES program in conjunction with a more efficient system for converting the reactor thermal energy to electrical power. The high capacity power technology element of our CSTI program will provide the advanced power conversion and heat rejection subsystems which could be coupled with the SP-100 reactor. This element will provide improvements in efficiency and system growth potential, survivability, autonomy, reliability, systems life, mass reduction and packaging. Our goal is to enable at least a fivefold increase in the electrical power that can be produced from the thermal output of the SP-100 reactor while more than doubling the system's power-to-weight ratio (see Figure 3).

The high payoff research and technology areas under investigation are:

- high efficiency (30 percent) dynamic conversion system
- advanced, high temperature and strength refractory alloys and composites
- power conditioning, control, and distribution components with orders of magnitude increase in radiation tolerance over current systems.

A significant part of the desired efficiency improvement will result from the use of a Stirling dynamic energy conversion system instead of the GES static thermoelectric conversion system. Testing of the 25kWe opposed-piston free-piston Stirling demonstration engine configuration at 650K has been completed, with 22 percent engine efficiency demonstrated and 90 percent of predicted power achieved. Further efforts are needed to better characterize the thermal losses and provide the capability to optimize performance and to improve prediction techniques. In FY 1988, a full-scale, superalloy space Stirling engine (shown in Figure 4) technology development program is being initiated. The performance, reliability, components life and dynamic behavior of the engine which will operate at 1050K will be investigated. These tests and evaluation will enable the development of an engine capable of taking full advantage of the 1300K delivered by the SP-100 GES reactor.

In addition to engine systems, advanced components are also being investigated. For example, experimental studies of advanced hydrodynamic bearings have been highly successful, increasing confidence for application of this minimum power loss bearing configuration in the space Stirling engine. Another component receiving major attention at this time is the engine's linear alternator. Analytical and experimental efforts have identified sources of excessive electrical losses in the alternator. Reduction of these losses will greatly improve the efficiency at maximum power conditions.

Advanced waste heat radiator concept studies are underway to identify innovative design approaches and technology needs. The radiator subsystem mass represents a significant portion of the overall system mass. Surface treatment techniques have been developed to increase the emissivity of various radiator materials instead of surface coatings. Applying these techniques which include acid etching, heat treating, abrasion, sputtering and arc texturing to SP-100 radiator materials have produced surface emissivities greater than the 0.85 design goal.

A supporting high temperature materials and structures research and technology effort is underway. Efforts to date have established a refractory metal (PWC-11) with superior characteristics to the GES baseline material (Nb-1Zr). The improved vacuum creep and creep-rupture behavior of the PWC-11 alloy (Figure 5) has been determined in the 1350-1450K temperature range. Test duration exceeds 16,000 hours and is still underway. The higher creep strength and stability of PWC-11 offers significant growth potential for the reactor power system. Another composite being studied, tungsten reinforced Nb-1Zr, has a potential factor of ten improvement in creep strength at 1400K temperature.

Experimental results obtained to date with the graphite fiber-reinforced copper matrix composites hold promise of smaller, lighter radiators and improved waste heat management systems (Figure 6). These composites have shown higher thermal conductivities and tensile strengths than unreinforced copper and beryllium at temperatures up to 1000K. Graphite/copper composites do not have the toxicity hazards associated with handling beryllium and have the added advantage of being capable of directionally controlling heat flow.

In addition to our work on dynamic conversion systems, good progress is being made in the development of higher efficiency thermoelectric materials in support of the GES. Figure 7 illustrates the performance gains (as measured by figure of merit which is directly proportional to conversion efficiency) that has been accomplished by the Jet Propulsion Laboratory research team. The microstructure of the improved SiGe/GaP samples shown in the figure have been segregated into the silicon-rich and germanium-GaP-rich regions as a result of high temperature heat treatments which are believed to be responsible for the performance improvement.

To enable the design of environmentally compatible space power systems, modeling and testing of the space environmental interactions are necessary. Samples of materials for radiators, reactor components and cabling, being considered for the SP-100 system, have been selected and are being prepared to be tested on-orbit. A test panel from an earlier Space Shuttle flight is shown in the payload bay in Figure 8. Preliminary ground testing of some of the materials is already underway in our Atomic Oxygen Test Facility at NASA's Lewis Research Center.

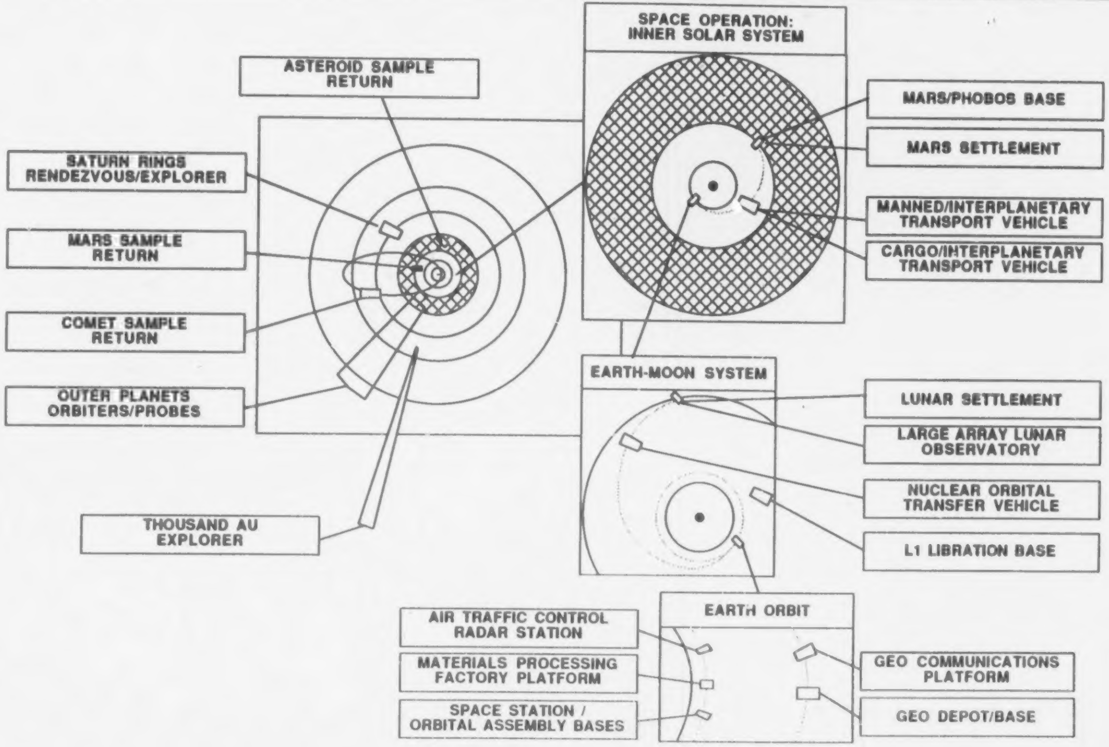
In summary, we consider nuclear power an essential technology in support of the National Space Policy. We have identified substantial benefits resulting from the use of nuclear power and have increased our support of those activities that will make high capacity space nuclear power a safe and technically viable option for civil missions.

Thank you, Madam Chairman.

LONG-RANGE FORECAST

POTENTIAL CIVIL APPLICATIONS

OAST



SPACE OPERATION: INNER SOLAR SYSTEM

ASTEROID SAMPLE RETURN

SATURN RINGS RENDEZVOUS/EXPLORER

MARS SAMPLE RETURN

COMET SAMPLE RETURN

OUTER PLANETS ORBITERS/PROBES

THOUSAND AU EXPLORER

MARS/PHOBOS BASE

MARS SETTLEMENT

MANNED/INTERPLANETARY TRANSPORT VEHICLE

CARGO/INTERPLANETARY TRANSPORT VEHICLE

EARTH-MOON SYSTEM

LUNAR SETTLEMENT

LARGE ARRAY LUNAR OBSERVATORY

NUCLEAR ORBITAL TRANSFER VEHICLE

L1 LIBRATION BASE

EARTH ORBIT

AIR TRAFFIC CONTROL RADAR STATION

MATERIALS PROCESSING FACTORY PLATFORM

SPACE STATION / ORBITAL ASSEMBLY BASES

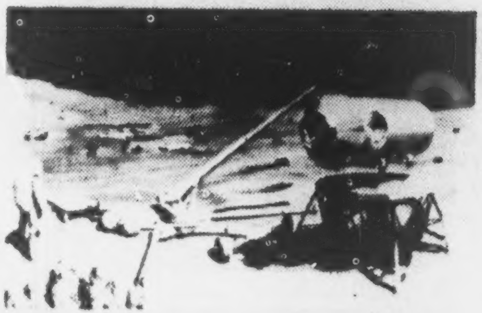
GEO COMMUNICATIONS PLATFORM

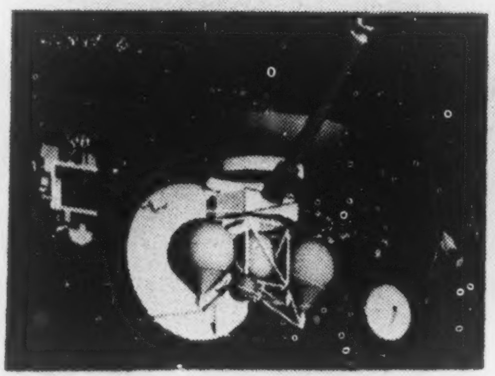
GEO DEPOT/BASE

Fig. 1

SP-100
SMALL REACTORS FOR PLANETARY EXPLORATION

- ASSESS USE OF SMALL REACTOR POWER SYSTEMS FOR NASA PLANETARY EXPLORATION MISSIONS
- 1-50 kWe





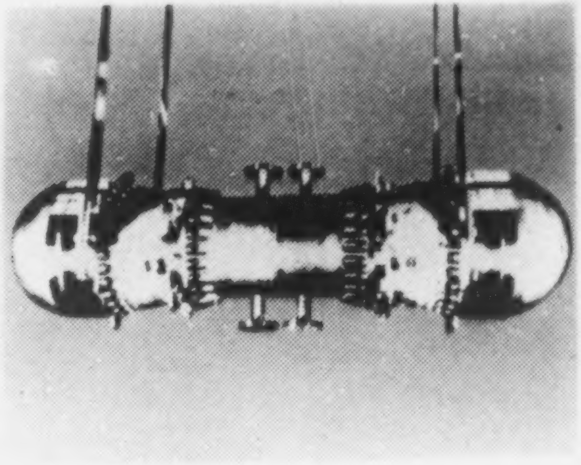
- 25 kWe REACTOR FOR ELECTRIC PROPULSION & SCIENCE
  - EQUAL OR REDUCED TRIP TIME
  - ENHANCED SCIENCE
  - INCREASED LAUNCH WINDOW
- SP-100 TECHNOLOGY ATTRACTIVE FOR SMALL REACTOR

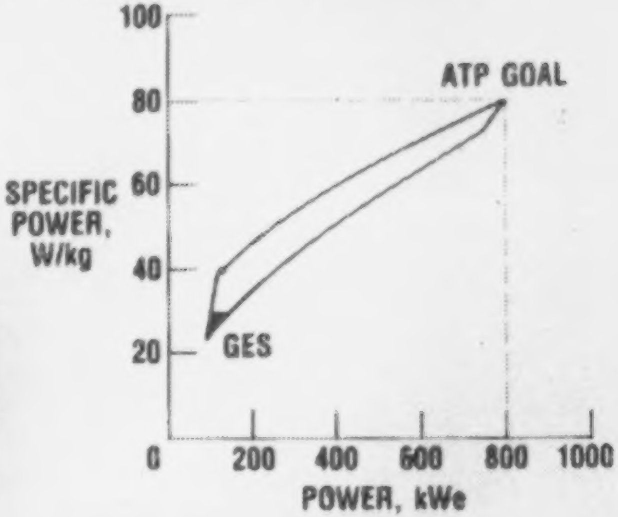
Fig. 2

NASA SP-100 ADVANCED TECHNOLOGY PROGRAM

- FOCUSSED TECHNOLOGY DEVELOPMENT TO INCREASE CAPABILITY OF SPACE POWER SYSTEMS USING GES REACTOR

25 → 80 W/kg
100 → 800 kWe





- FREE PISTON STIRLING ENGINES
- ADVANCED RADIATOR
- POWER CONDITIONING & CONTROL
- MATERIALS

Fig. 3

SUPERALLOY STIRLING SPACE ENGINE (SSE) REFERENCE SPACE DESIGN

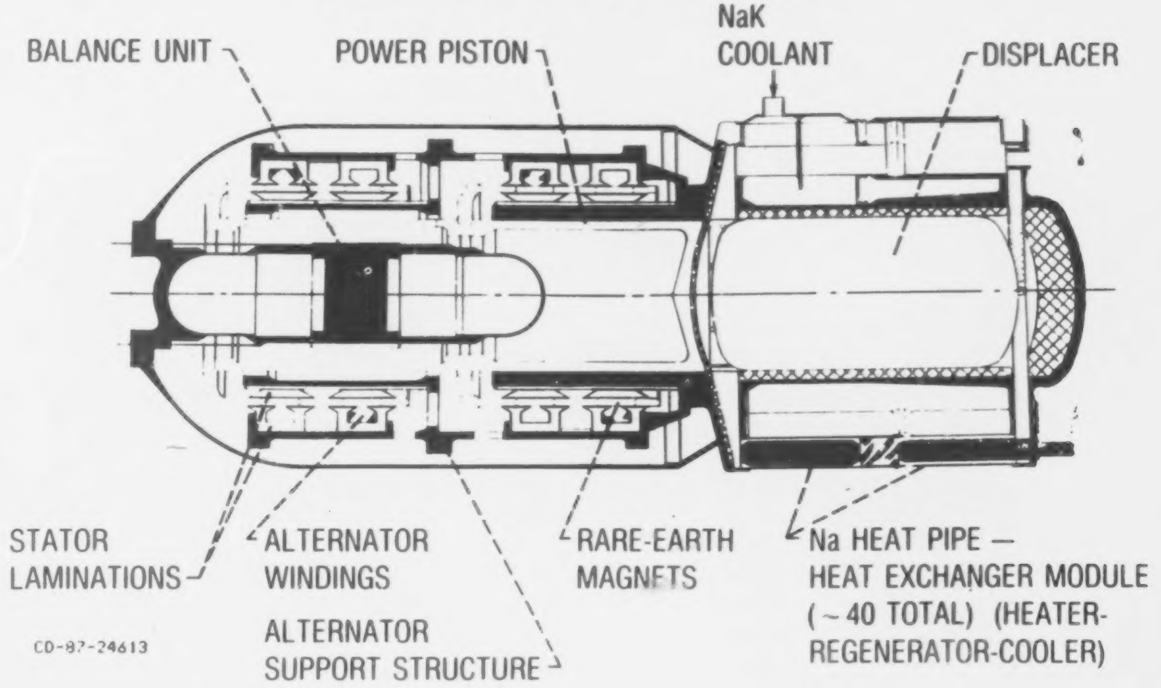

NaK
COOLANT
BALANCE UNIT
POWER PISTON
DISPLACER
STATOR
LAMINATIONS
ALTERNATOR
WINDINGS
ALTERNATOR
SUPPORT STRUCTURE
RARE-EARTH
MAGNETS
Na HEAT PIPE —
HEAT EXCHANGER MODULE
(~40 TOTAL) (HEATER-
REGENERATOR-COOLER)
CD-87-24613

Fig. 4

PWC-11 ALLOY EXCEEDS THE DESIGN REQUIREMENTS FOR SP-100 NUCLEAR SPACE POWER SYSTEMS

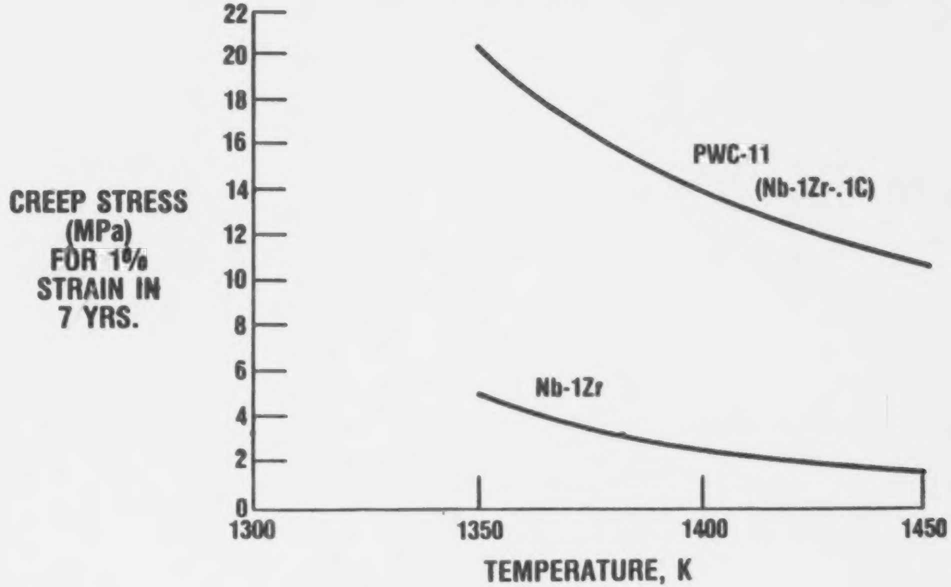


Fig. 5

GRAPHITE FIBER REINFORCED COPPER MATRIX COMPOSITES OFFER POTENTIAL FOR HIGH THERMAL CONDUCTIVITY SPACE POWER RADIATOR PANELS

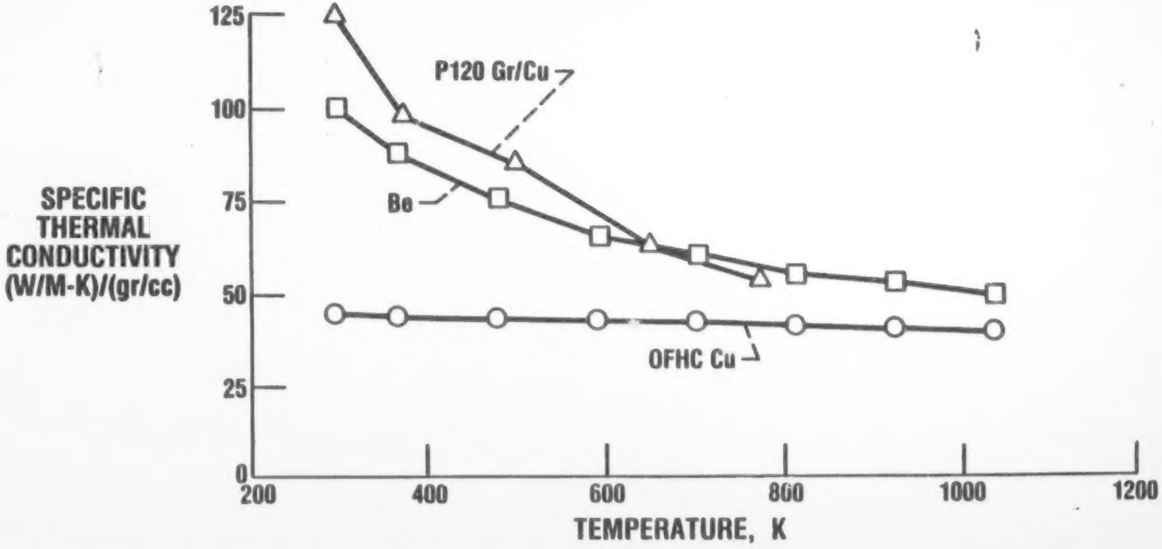
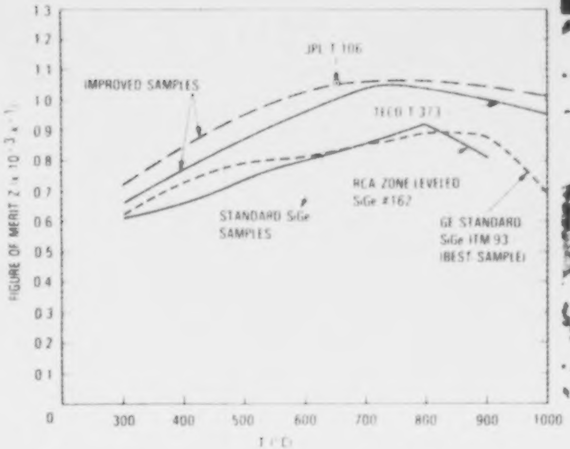
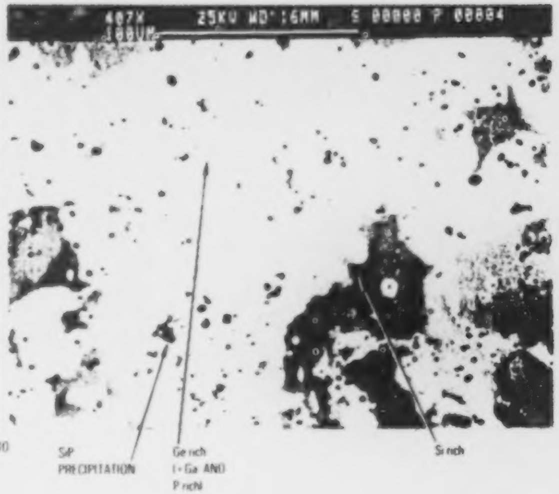


Fig. 6

SiGe/GaP RESEARCH



THE FIGURE OF MERIT Z OF THE BEST JPL AND TECO SiGe/GaP SAMPLES COMPARED TO THE BEST STANDARD SiGe SAMPLES


407X 25KU WD:16MM S 00000 P 00004
100UM
SiP PRECIPITATION
Ge rich (+Ga AND P rich)
Si rich

MICROSTRUCTURE OF AN IMPROVED SAMPLE SHOWING THE Si-rich AND THE Ge-P-Ga-rich REGIONS WHICH RESULT FROM THE HEAT-TREATMENTS

Fig. 7

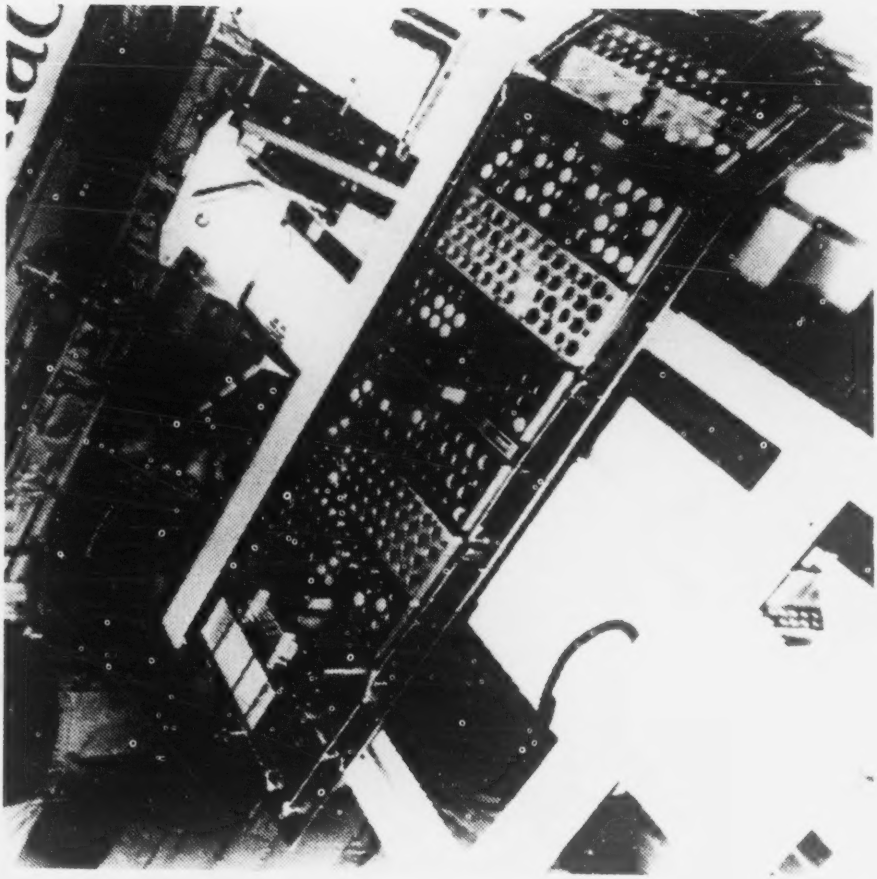


Fig. 8

DISCUSSION

Mrs. **Lloyd**. Thank you very much, Mr. Reck.

It's come to my attention that the Pathfinder Program may be on the Appropriation Committee's chopping block, as the Committee deliberates over the NASA fiscal year 1989 budget request.

I'd like for you to comment on the impact on not only the future of our space activities as it relates to approaches in mission, but specifically the impact that it would have from the loss of the development of power systems for our future NASA missions as well.

Mr. **Reck**. There's been a great deal of attention focused on the space program over the past couple of years. That's including the National Commission on Space, which has examined opportunities in future space missions, and I referred to Dr. Ride's report, which also identified a number of exploratory missions.

I believe that in light of the opportunities that have been identified there, that the President's new national space policy is endorsing a position that says the United States should seek leadership in space activities, and that there is a future for this country in space missions and exploration is a very significant part of that.

Pathfinder is a significant part of the President's new initiative.

Mrs. **Lloyd**. In the development of power systems for our future missions, what would the impact be?

Mr. **Reck**. Certainly the high-capacity power needs are a very critical part of Pathfinder and I think they're interdependent. I think without the Pathfinder requirements, the requirement for high-capacity power is certainly not as strong and may not exist, and I think our support of the SP–100 is really dependent on those future space needs.

Mrs. **Lloyd**. Well, you know, the NASA budget—there's a lot of comment on the size of the NASA budget, and I was just really curious what the percentage of the budget that really goes for the Civil Space Technology Initiative and the Pathfinder Program. This couldn't be a large part of the NASA budget.

Mr. **Reck**. In fiscal 1989 the Pathfinder is proposed at a level of $100 million, and that represents, I believe, less than one percent, about seven-tenths—three-quarters of a percent. If the CSTI were added to that, that would nearly double it. I believe the CSTI in the fiscal year 1989 request is $157 million. So, that would be about $257 million total out of the budget request and under 2 percent.

The nuclear power portion of that is, of course, only a part of CSTI and Pathfinder. The nuclear part of CSTI, which is supporting the Advanced Conversion Technology Activities in NASA, in fiscal year 1989 will be about $14 million, and the SP–100 share of Pathfinder in fiscal 1989 will be about $30 million.

So combined, those two come to about $45 million out of the $250 million that will be spent on those initiatives. So it really is very small

Mrs. **Lloyd**. It seems to me that's a pretty good investment.

Mr. **Reck**. I think so.

Mrs. **Lloyd**. The NASA budget, when you look at the necessity of developing our power systems—well, I'm concerned that even if our Ground Engineering Systems program proves to be successful, and certainly I think it will be, that the application of nuclear reactors to the generation of electricity in space will be dependent on the flight demonstration of other systems.

I'd like for you to give us NASA's view of this matter. Do you think that NASA's mission planners would incorporate nuclear power into their space craft without a successful flight demonstration?

Mr. RECK. I think we clearly believe that they would not. I think it's essential that the flight demonstration program take place. Unquestionably, the uncertainties associated with cost and schedule of any new technology, and certainly a technology as advanced as space nuclear power, requires that we demonstrate in flight that capability before it will be adopted by the mission planners.

Mrs. LLOYD. Well, what, in your view, would constitute such a flight demonstration program?

Mr. RECK. For several years, the SP-100 Program has been examining a reference flight mission that's incorporated the SP-100 reactor system with an onboard load and we have been assuming that that would be an electric propulsion system.

In fact, I believe within the past several months we've, as part of the SP-100 Program, initiated a contracted study which will further define what that reference flight mission would be—targeted for the mid-1990's. As I say, we currently anticipate that it would be an SP-100 reactor at the 100-kilowatt level, and most likely, demonstrating electric propulsion which could also be used for on-orbit maneuvering—there may be other experiments that will be carried onboard as well.

Mrs. LLOYD. Thank you very much.

Mr. Morrison?

Mr. MORRISON. Mr. Reck, I want to start by saying that space nuclear power, for most of us, is really the exciting arena, the new world that's out there. I've attended a number of meetings, including with students, and find that this is the——

Mrs. LLOYD. Will the Gentleman yield?

Mr. MORRISON [continuing]. The arena—I'd be glad to.

Mrs. LLOYD. I see some smiles in the audience. They're agreeing with you.

Mr. MORRISON. Okay. That's great. I think we're attracting people into our universities and that next super-generation of scientists, based on the potential of this program, and I certainly have to agree with the Chairman that we've got to retain these funds in the budget. As I've looked at Pathfinder and look at the very small percentage that it is, it is, I think, inordinately important in the total mix of things.

So, I, for one, and I hope this Subcommittee can be helpful in keeping Pathfinder on track as we move on into the future.

You've made sort of a statement about a mission for SP-100. Some of us feel strongly that that's essential, and what you've just described, as far as propulsion as well as demonstration of electrical output in space and other forms, makes up the mission that you have in mind.

Mr. RECK. There are a number of mission opportunities. We have no specific mission that has been approved as part of NASA's budget at this point that involves high-capacity nuclear power, but as part of the Office of Exploration's study activities, they're considering a number of manned, as well as unmanned, exploration missions to the Moon and to Mars and other unmanned exploration activities as well.

We envision that those surface exploration activities, for example, would be one of the largest demands and certainly demand the highest capacity nuclear power of any of the missions that we're studying.

For example, one of the largest benefits associated with nuclear power would be associated with a manned long-term or perhaps permanent outpost on the lunar surface. There, where there's a long-night cycle, on the order of 14 days, we find that virtually all of the mass, 90 percent of the mass of the power system is in the storage capacity, and if you translate that back to the number of launch vehicles—heavy-lift launch vehicles—that would be required to supply that power system to low earth orbit, it's very large. It's over 65 heavy-lift launch vehicles that will be required in terms of making up the difference in weight between a nuclear-powered system and photovoltaic system.

Those are potential missions. We're studying those missions, as well as others. We can identify other missions which have significant benefits for nuclear power. But at this point, and for the next several years, we'll be studying those missions opportunities and using those to evaluate and identify the most critical technologies to develop.

But I think clearly, nuclear power is one of the most critical.

Mr. **Morrison**. I think we would urge you to identify the mission at the earliest reasonable date so that we can use it as part of the justification for the dollars we are spending, you are spending in SP-100 and other space power options. And I do think we need that mission out there within the next several years, as something just to shoot for.

We are aware that some of the other folks in the world who are involved in energy sources in space have not been as cautious as we have been. Are we going completely overboard as far as concern about safety, before we put a nuclear reactor into space?

Mr. **Reck**. I think that we are not at this point. I think it's critical that we include safety as an integral part of the planning and the design and every step of the way, and I think that's why both ourselves and the Department of Energy in developing the SP-100 reactor system are attempting to do. We're trying to examine every possible scenario associated with the launch, pre-launch and operation of the nuclear systems, as well as the end-of-life disposal, and all of the emergency situations that might arise in the course of that operation. And to provide the safety systems and be able to identify potential scenarios and deal with those.

I think that it's absolutely critical that we be as cautious as possible and I think we're going to have to convince everyone that we have accommodated all of those possible circumstances.

So, I don't believe that we are. I don't see any evidence of that and I think it's crucial that we continue to recognize safety as the prime factor in consideration.

Mr. **Morrison**. I would agree that the perception is going to be vitally important. I just wonder, as I look at what others are doing with almost what seems to be a disregard, and we seem to be going so aggressively in the other direction.

I would agree with that direction, and know that you've looked at the big picture in your total planning.

What about the difference between low and high orbits? Intentionally planning on nothing but the highest orbit as far as reactors?

Mr. RECK. At this point we're continuing to look at both high Earth orbit applications, as well as low Earth orbit applications. I feel that with the appropriate consideration that nuclear reactors can be applied to low Earth orbit.

I think that it's absolutely essential that you provide a safe and reliable propulsion system on board, such that in the event that an emergency occurs with the reactor and it's shut down, or at the end of life, the reactor can be boosted to a higher orbit with a lifetime that's sufficient to endure the decay of the products of the reaction.

I think with that safeguard, as well as other safeguards, that we believe that it's still possible to utilize reactors in low earth orbit.

So we're continuing to look at that as well as applications in higher orbits or in geosynchronous orbits.

Mr. MORRISON. That, I think, sounds very reasonable and we commend you for some very good work. Look forward to working with you.

Mr. RECK. Thank you.

Mr. MORRISON. Thank you, Madam Chairman.

Mrs. LLOYD. Thank you very much, Mr. Morrison.

Thank you, Mr. Reck, as well.

Our next witness is certainly no stranger to this Committee, Mr. Victor Stello, who is the Executive Director for Operations at the Nuclear Regulatory Commission.

We do welcome you today and we are weighing your testimony, as well. Your written statement will be made a part of the record and you may summarize and proceed as you wish.

STATEMEMT OF VICTOR STELLO, JR., EXECUTIVE DIRECTOR FOR OPERATIONS, U.S. NUCLEAR REGULATORY COMMISSION, WASHINGTON, DC; ACCOMPANIED BY THOMAS KING, BRANCH CHIEF

Mr. STELLO. I will summarize very briefly the testimony to provide enough time for you to get in any questions you may have.

It is certainly a pleasure to be here this afternoon. I have with me Mr. Thomas King, who is the Branch Chief and responsible for the work on the high temperature gas cooled reactor.

Let me at the outset say that the Commission is very interested in advanced reactor designs, very interested in standardization, and looking to do what we can to provide a very stable and responsible regulatory framework as these new designs evolve.

As you are aware, we have been actively involved in standardization and have issued a standardization policy statement. Hopefully in the near future we will have some additional regulations dealing with that issue. We have also issued a policy statement on advanced reactors.

On the subject you asked me to speak to you about this afternoon, the high temperature gas reactor, we have been making good progress. We have been reviewing the DOE proposal now for some time and expect to complete our review and present our findings to our Commission sometime in the next two to three months in this area. This will basically conclude of our activity proposed by DOE until and unless DOE asks us to do more.

During our review we have observed some advantages that are inherently associated with the gas reactor design. One is their very low heat-up time. The high temperature gas reactor design allows some concepts to be incorporated into the design which appear to be very advantageous from a regulatory point of view, a safety point of view.

There are, on the other hand, a number of problems, that one has to deal with, with the proposed design. One such issue is the lack of containment for the gas reactor design. The lack of containment is being justified based on those inherent features that are built into the design. This may turn out to be the conclusion reached by the Commission when they complete their review. It is clearly a major policy question that the Commission will have to face.

We cannot say at this time what our conclusions will be, simply because we are not finished. However, it does appear that the design as proposed will allow us to conclude that it meets and will probably will even exceed the criteria as set forth in the Commission's safety goal policy statement. That is principally because of these features that are inherent in the design.

We believe that the design does have the potential to provide the high level of safety commensurate with the Commission's safety goal, and we will have to, of course, wait until the review is finished before we reach any firm conclusions on it.

That concludes, Madame Chairman, my brief introduction. I trust that the prepared statement will be incorporated into the record, I am prepared to answer any questions you may have at this time.

[The prepared statement of Mr. Stello follows:]

PREPARED TESTIMONY
SUBMITTED BY
UNITED STATES NUCLEAR REGULATORY COMMISSION

TO

SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION
COMMITTEE ON SCIENCE AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES

CONCERNING
NRC'S ACTIVITIES ON
THE MODULAR HTGR

PRESENTED BY
VICTOR STELLO, JR.
EXECUTIVE DIRECTOR FOR OPERATIONS

SUBMITTED: March 16, 1988

Thank you Madam Chairman. I am pleased to appear before you and members of your Subcommittee today to discuss the Nuclear Regulatory Commission (NRC) activities with respect to the Modular High Temperature Gas-Cooled Reactor (MHTGR). Other members of the NRC staff involved in this work accompany me today. I would like to begin my testimony by briefly providing you with some background on these activities, then proceed to describe our current review effort, including its status, and also provide the Subcommittee with some preliminary conclusions.

Background

In September 1986, we presented to your Subcommittee our plan for the review of a Department of Energy (DOE) sponsored conceptual design for a Modular High Temperature Gas-Cooled Reactor (MHTGR). During that same period, we received from DOE a Preliminary Safety Information Document (PSID) which described the conceptual design for the MHTGR plant (a 540 Mwe plant consisting of four modular reactor units, each contained in an underground concrete cavity). Also, early in 1987 we received additional documentation on the MHTGR design consisting of a Probabilistic Risk Assessment, an Emergency Planning Basis Document and a Regulatory Technology Development Plan. Our review of these documents has been proceeding consistent with our plan as described to you in September 1986 and consistent with the guidelines put forth by the Commission in their July 1986 Advanced Reactor Policy Statement.

Review Status and Approach

Our review of the MHTGR, which will be summarized in a Safety Evaluation Report (SER), is scheduled for completion in late Spring of this year. As a result of a recent reorganization within NRC, the responsibility for this review has been transferred from NRC's Office of Nuclear Reactor Regulation to the Office of Nuclear Regulatory Research. However, continuity of the review staff has been maintained.

The review has consisted of an examination by our staff of the DOE submitted documentation; the staff's efforts have been augmented by technical assistance from consultants at Oak Ridge and Brookhaven National Laboratories. In addition to assisting us in the review of the documentation submitted, these consultants have also performed independent evaluations pertaining to the performance of the MHTGR passive decay heat removal system, the inherent response to reactivity transients, graphite fires, and other fundamental areas of MHTGR safety. As part of the review, the staff and its contractors have held a series of meetings with DOE and its contractors and, in response to staff questions and comments, DOE has submitted eight amendments to the PSID. A ninth and final amendment is expected in the near future responding to staff questions and comments associated with the remaining issues under review.

The purpose of our review is to provide guidance on the acceptability of the MHTGR design early in the design process. Accordingly, the output from this review is being coordinated among other affected NRC offices, the Advisory Committee on Reactor Safeguards and the Commission. The approach applied in the review is to develop licensing guidance that ensures that the level of safety achieved by the MHTGR is at least equivalent to that achieved by those evolutionary advanced light water reactor (LWR) designs currently under review by NRC. To accomplish this, the staff is building upon LWR licensing criteria, wherever practical, and utilizing the safety guidance put forth in the Commission's Severe Accident, Safety Goal, Advanced Reactor and Standardization policies to develop criteria to address those unique aspects of the MHTGR. Proposals from DOE and its contractors regarding design criteria are also being considered. The guidance and criteria decided upon will be documented in the forthcoming SER.

Design Acceptability

Our review of the MHTGR has concentrated on those proposed aspects of the design that accomplish the three basic safety functions that all nuclear reactors must accomplish - namely, reactor shutdown, decay heat removal and containment of radioactive material. The key issues identified in our review result from the way the above functions are accomplished, as compared to LWRs. Specifically, DOE and its contractors contend that some traditional means of accomplishing safety functions (such as a containment building) are not needed because of the unique characteristics of the MHTGR. As a result, certain policy issues are being addressed in our review so that we can provide comments on the acceptability of the design from a regulatory perspective. These policy issues are (1) the range of accidents which must be considered in design, siting, and emergency planning, (2) the acceptability of the proposed mechanistic approach to the calculation of the release of radioactive material (3) the necessity for a conventional containment building, and (4) evaluating the acceptability of proposed changes in the need for offsite emergency evacuation and sheltering. The staff's proposed resolution of these issues will be reviewed by the Commission before we finalize our licensing criteria and communicate these criteria to DOE.

In addition to the policy issues listed above, there are some additional significant technical issues that the staff is still in the process of discussing with DOE. Examples of these issues are fuel performance and reactor vessel integrity under accident conditions. Additional information is expected from DOE on such issues as these before completion of the NRC review.

It should be noted that certain attributes of the MHTGR may also facilitate its potential for licensing. Examples of these attributes are the simplification of safety systems, the reduced dependence on operator actions and active components and systems, the ability to safely withstand certain low probability events and the potential for a reduced emergency planning zone radius. Although it is too early to make a final judgement in this regard, it is believed that such attributes have the potential to simplify our licensing review and support a timely licensing process.

Regarding standardization, we indicated to you in our testimony of September 1986 that NRC was preparing a policy statement with respect to standardization and that the staff was planning to address the subject of standardization as part of its review of the MHTGR. The Commission did issue its Policy Statement on Nuclear Power Plant Standardization in September 1987, and based upon our review to date, the staff believes that the MHTGR program's plans for achieving a standardized design are consistent with this policy. Commission review of the policy aspects of the MHTGR program's standardization plans is planned in the near future.

Preliminary Conclusions

Based on the review to date, let me discuss some preliminary conclusions we can offer at this time. The general safety advantages of the MHTGR, like other HTGRs, are (1) its slow response to core heatup events, because of the large heat capacity and low power density of the core, and (2) the very high temperature that the fuel can sustain before significant fission product release (about 1600°C). Also, like other HTGRs, its major potential vulnerabilities derive from the need to protect metal components from continued exposure to elevated temperatures during postulated transients. Accordingly, the MHTGR design has the potential to provide a high level of safety and can be judged qualitatively at this time to have the potential to offer enhanced safety in certain areas in comparison to LWRs. This conclusion is, of course, contingent upon satisfactory resolution of the technical issues identified in our review and upon successful completion of necessary R&D programs.

While we cannot at this stage of the review quantitatively confirm the radioactive release estimates formulated by DOE for the spectrum of accident events it analyzed, we believe that the potential low frequency and low consequence of MHTGR severe accidents will allow the design to meet and probably exceed licensing criteria which are consistent with NRC's Safety Goal Policy. We also expect that certain worst-case events of extremely low probability will not exceed the NRC radiation dose guidelines used for siting purposes during the first 2 or 3 days after event initiation.

Summary

In summary, we believe on the basis of our review thus far that the MHTGR is a potentially acceptable design. However, before a final decision on the acceptability of the design can be made, key policy issues on source term, containment requirements and the acceptability of proposed changes in the need for offsite evacuation and sheltering must be decided. Also, a staff position must be reached on the acceptability of the plans for resolution of the remaining technical issues as discussed above. As we complete our review of the MHTGR conceptual design, we are focusing on the above items.

In concluding, I should mention that the Commission's activities directed toward the review of advanced designs will continue. This includes continuing to interact with DOE and its contractors on the acceptability of the MHTGR concept as well as on the acceptability of the two DOE sponsored liquid metal reactor concepts submitted for our review. In addition, we currently have reviews underway on three large advanced light water reactor standard plant designs as well as a review of a utility sponsored Advanced Light Water Reactor Requirements Document. It is our plan to continue these activities as well.

Madam Chairman, this completes my prepared statement. I would be pleased to answer any questions you may have.

DISCUSSION

Mrs. **Lloyd**. Thank you very much, Mr. Stello. In your testimony you mentioned graphite fires, which is a source of the radiation emissions from the Chernobyl accident.

Are graphite fires the Achilles' heel of the MHTGR technology?

Mr. **Stello**. I doubt that. There are significant differences in both.

Mrs. **Lloyd**. Mr. Stello, let me back up. You said, "I doubt that." Could you be a little bit more definitive?

Mr. **Stello**. I'm going to.

Mrs. **Lloyd**. Okay, good.

Mr. **Stello**. The major differences in Chernobyl and the high temperature gas reactor as proposed by DOE, and I might add the Fort St. Vrain reactor, is that the Chernobyl reactor had available to it water and of course the zirconium tubing and the water can cause metal-water reaction and generate an environment, once it is breached, to cause the graphite fires.

We do not believe that the features, and we are not finished with the review, are an Achilles heal in safety. We believe that the differences between them are sufficient as to not find some fundamental flaw in the licensing process because of it. But again I would have to caveat we are continuing to review that aspect of it although we have reviewed it rather extensively at Fort St. Vrain.

Mrs. **Lloyd**. All right. What are the major safety issues you are concerned about, and what do you expect to come from these evaluations?

Mr. **Stello**. Let me suggest that the major issue that I see, or one major issue, is that the design as it is proposed today does not include a conventional containment structure. Now the containment is not included simply because the inherent features of that design suggest, based on analyses, that one is not necessary. The very high temperature capability of the fuel and the passive features that are built into it, as well as some fission product retention capability in the vessel itself are such that one does not need a containment structure.

Well, that is philosophically quite different than most of the light water designs and will be a particularly significant issue for the Agency to deal with in deciding whether it is okay to go forward. That would be an example of what I think is perhaps the most significant issue.

A second issue is emergency preparedness. Based upon the analyses to date, it does not appear that these designs would have to have the kind of emergency preparedness requirements that we now build into all of the existing commercial reactors. It may be correct that these requirements are not needed, but as you would expect, this will be an area in which there will be considerable focus at the Commission level as they review this design.

These are just two examples of very fundamental, philosophical issues that the Commission will have to face. I don't mean to suggest that there is any technical reason that suggests that those particular aspects of the design are somehow flawed. DOE has provided a design and an analysis to support moving in that direction.

Mrs. LLOYD. Good. Would you provide the Subcommittee with your NRC staff papers analyzing the technical safety of the MHTGR?

Mr. STELLO. We'll be happy to. We expect to have our safety evaluation report finished in the next two to three months and when it is finished we'll be very happy to provide that to the Subcommittee.

Mrs. LLOYD. I understand that you have done a lot of the technical analyses, and that was what I really wanted, Mr. Stello.

Mr. STELLO. We will be happy to provide you all of the analyses that we have done to date, and in addition we will provide you with a copy of the SER.

[This material is continued in Subcommittee files.]

Mrs. LLOYD. Thank you very much. I appreciate it.

Well, Mr. Morrison?

Mr. MORRISON. Thank you.

Mrs. LLOYD. The bell—do you want to proceed?

Mr. MORRISON. No, let's proceed. I think we can do this.

Mr. Stello, I asked Mr. Garrish sort of a philosophical question about the procedure that the Department is going through on working on new technologies and the time frame seems to be that, oh, mid-1990's potentially new orders for new advanced concepts on light water reactors, probably not too much different than today's, then moving on into liquid metal, HTGR concepts on to the future.

Are your activities at NRC compatible with that sort of schedule, or are you concentrating your work now on what might appear to be the need for standardization of designs, pre-approval of designs for light water reactors?

Mr. STELLO. Let me give you a personal view of where I believe the Agency needs to go to provide a very stable regulatory framework that will be needed for the future.

In simple terms, it is a standardized design that has been certified and incorporated into our regulations, as well as siting specifications that have been approved and incorporated in our regulations. In a one-step licensing process, a utility can select a site and select a design, go to one hearing, and then be confident that he can construct and operate that facility. This particular framework in my view is very, very important to have in place in the future. That is the direction we are moving toward.

I am not suggesting that this particular approach is unique to the light water designs. In fact, the proposals by DOE anticipate the possibility of certifying a high temperature gas reactor design consistent with what I have said so the designs too will also be available.

The ultimate question of what will the future generation of reactors look like in my view is strictly a function of the marketplace—that is, in simple terms, what the utilities judge to be the right designs consistent with their needs and their notions of risk, and I am not really equipped or able to answer how that marketplace will develop in the future.

Mr. MORRISON. I'm convinced, Mr. Stello, that part of that marketplace is in your hands, that is, what you do, what you are prepared for is going to drive what the utilities are going to be able to afford.

Mr. STELLO. Congressman Morrison, I agree with you fully. I think a great deal of what the future of our country will look like in terms of nuclear power will depend in large measure on whether there is a stable licensing process for the future. That is why I believe so deeply that the philosophy of regulation for the future, which includes certified designs, pre-approved sites and one-step licensing is very, very important. I would urge Congress to do whatever they can to support legislation that in any way makes a statement as to what Congress' view is. It would help.

Mr. MORRISON. Certainly you'll get that kind of statement from this Subcommittee. I wish I could speak for the rest of the Congress.

Where are you as far as beginning some safety review work of the potential liquid metal reactor designs?

Mr. STELLO. Those two designs are also scheduled for review, and the reviews will be finished in about the next four to five months, July to August time frame.

Mr. MORRISON. So they are just a month or so behind the work you are doing on the high temperature gas reactors?

Mr. STELLO. That's correct.

Mr. MORRISON. Any clues as to where we are headed there? Passive safety is certainly inherent in those as well?

Mr. STELLO. Yes. They have many of the fundamental policy issues that I described with respect to the high temperature gas reactor such as emergency planning and containment design. These issues apply to those reactors as well.

I am not aware of or see any fundamental design feature that again precludes acceptability. We have not identified any. There are major policy issues that we are going to have to address.

I might add that our advanced reactor policy statement encourages this kind of design innovation.

Mr. MORRISON. That is appropriate.

From the view of licensability, which seems to be one of the Congressional mandates on, say, new defense production facilities for the Department of Energy, how quickly could you, if Congress pushed for a new type of reactor for defense production, could you be in a position to certify that the facility was licensable?

Mr. STELLO. Well, I can't give you an answer in terms of a chronological time, because I don't know that we know all of the differences that would be proposed, for example, differences between the current high temperature gas reactor design as we know it, and as it might be modified to be used for a production reactor.

We are aware that consideration has been given to such an approach. We know that there would be differences and we would have to have an opportunity to see what those differences are.

We would be able to take advantage of the work that has already been done to the extent that the designs are consistent. There would be many things consistent in the production reactor and in the proposed commercial application high temperature gas reactors, but until you have a design in front of you and have the time to review it, it is hard to judge. We would be able to take advantage of all of the work that we have done and it would depend on how many things DOE suggests need to be changed in that design to make it suitable for a production reaction.

Mr. **Morrison**. I'm really throwing you a curve, of course, in asking that question, because my hope is that Congress settles for maybe converting the state-of-the-art light water reactor, which you could probably license right away.

Thank you. Other than staying here and having a field day in the absence of the Chairman, I'd better have a recess until she gets back.

[Recess.]

[Questions and answers for the record for Mr. Stello follow:]

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

April 29, 1988

The Honorable Marilyn Lloyd, Chairman
Subcommittee on Energy Research and
  Development
Committee on Science, Space, and Technology
United States House of Representatives
Washington, D. C. 20515

Dear Madam Chairman:

I am enclosing responses from the Executive Director for Operations, Mr. Victor Stello, to your questions of April 1, 1988. These questions resulted from your Subcommittee's March 16, 1988 hearing on Nuclear Fission.

Should you have any further questions, please contact me.

Sincerely,

John C. Bradburne, Director
Congressional Affairs
Office of Governmental and
  Public Affairs

Enclosures:
As Stated

cc: The Honorable Sid Morrison

QUESTION 1 Last year it was reported that you expected to issue your safety evaluation report for the MHTGR in January of this year. Your testimony indicates that it is now scheduled for completion in late spring. What are the reasons for the delay?

ANSWER:

The primary reason for the delay in the issuance of the MHTGR SER is the significance of the major policy issues that were raised during the review of the MHTGR and LMR conceptual designs. These issues are described in the response to Question 6 and they challenge some of the fundamental requirements used to license current nuclear power plants. The review of these issues has required extensive deliberation within NRC in order to establish criteria to use in determining the licensability of such innovative designs. This extensive review has taken longer than anticipated because of the importance of the issues being addressed and because the staff has had to look at all aspects of the MHTGR design to ensure that the key safety characteristics of the MHTGR are not vulnerable to events or failures involving support systems, external events, human errors or other interactions which could affect performance of safety functions. In addition, the development of the licensing criteria for these innovative concepts has resulted in additional meetings with and further analyses by DOE and their contractors.

QUESTION 2 Please identify the safety issues you are most concerned about regarding the MHTGR technology and what your preliminary expectations are regarding these issues?

ANSWER

In addition to the policy issues described in response to Question 6, we are primarily concerned with the following issues. We will address these issues in our SER on the MHTGR:

- fuel performance under accident conditions and its supporting data
- reactor vessel integrity under certain accident conditions
- reactor physics methodology and data base
- basis for assumed fission product retention capability of the reactor cavity
- design requirements for certain structures under elevated temperature conditions

Although we believe that these issues can be resolved, R&D will have to be performed by the applicant to substantiate the analytical assumptions prior to licensing.

QUESTION 3. The Subcommittee's assessment of the MHTGR technology is that it is a fail safe reactor. It is thus very close to being inherently safe and would be a significant advance in nuclear power plant technology. What is your critical reaction to this assessment?

ANSWER.

The MHTGR design objectives include high heat capacity in the graphite core, passive decay heat removal, and passive reactivity control features. Additional R&D and full-scale testing of the key safety features will have to be performed by the applicant before the NRC staff can firmly conclude that the design objectives have been met, but we do believe the MHTGR has the potential to be a significant advance in nuclear power plant technology. However, we would not go as far as saying it is fail safe. Like all reactors, its safety is dependent upon quality construction, disciplined, well managed operation, maintenance, periodic inservice inspections and surveillance. In the case of the MHTGR, its safety is particularly dependent upon the quality of the fuel. Therefore, there are failures (both of equipment and administrative systems, i.e., QA, operations, etc.) which could affect the safety of the MHTGR.

QUESTION 4. On page 3 of your testimony, you likened the MHTGR technology to the advanced light water reactor designs currently under NRC review. The Subcommittee has viewed the MHTGR as a step beyond these advanced LWR designs because it can sustain a complete loss of coolant and still limit radiation releases to those not requiring offsite sheltering or evacuation. What is your most critical reaction to this assessment? Do the advanced LWR designs also have this capability?

ANSWER.

Based upon our review to date, it appears that the high temperature capability of the MHTGR fuel provides the potential to sustain an event that leads to depressurization, including loss of forced circulation. However, we cannot firmly quantify the level of risk or potential for radiation releases from such an event until the issues discussed in Question 2 have been thoroughly researched. The advanced LWR designs must retain water in the core region to maintain fuel integrity, however several of these designs propose doing this with passive means and without the need for forced circulation. These designs are also expected to limit radiation releases to those not requiring offsite sheltering or evaluation.

QUESTION 5. Please provide the subcommittee with a time line chart showing the expected NRC activities on the Advanced technologies?

ANSWER:

A time line chart is attached that shows the NRC review activities for the following nuclear power plants:

1- Advanced Boiling Water Reactor (ABWR)

2- RESAR SP/90

3- CE System 80+

4- AP-600

5- MHTGR

6- PRISM

7- SAFR

ENCLOSURE TO QUESTION 5

Fig. 7

	FY87	88	89	90	91	92	93
ABWR				F		C	
RESAR SP/90			P			F	
CE SYSTEM 80+					F	C	
AP600		L					F
MHTGR		S				P	
PRISM		S					F
SAFR		S				F	

P = Preliminary Design Approval
F = Final Design Approval
C = Certification
L = Licensability Submittal
S = Safety Evaluation Report on Conceptual Design

QUESTION 6. Please summarize the important unresolved safety issues concerning the advanced reactors under review?

ANSWER:

The NRC staff is currently working on the following key licensing issues that affect the MHTGR, PRISM and SAFR advanced reactors:

(1) the range of accidents which must be considered in design, siting, and emergency planning,

(2) the acceptability of the proposed mechanistic approach to the calculation of the release of radioactive material,

(3) the necessity for a reactor containment building,

(4) evaluating the acceptability of proposed changes in the need for offsite emergency evacuation and sheltering, and

(5) the approach to design certification.

In terms of safety, the most important of these issues is the question of the necessity for a reactor containment building.

In addition, each individual concept also has safety issues unique to its design still under review by NRC. For the MHTGR these are listed in the response to Question #2. For the LMR these include fuel performance, performance of passive shutdown and decay heat removal systems and response of the plant to certain postulated events.

QUESTION 7. Is nuclear proliferation an NRC issue with any of the advanced reactors under review? If so, what is the issue and what is the expected course of resolution? What is your view on the actinide burning potential of the LMR design being pursued within DOE?

ANSWER.

The LMR designs utilize plutonium as the primary fissile material. As a result, fuel reprocessing becomes necessary and nuclear proliferation becomes an issue. However the LMRs may use onsite fuel reprocessing in an attempt to reduce proliferation concerns. The proposal to colocate power generation and fuel reprocessing requires careful consideration from the point of view of regulation as well as from the point of view of design, construction, operation, and management. Information on the LMR fuel cycle including non-proliferation considerations is currently being developed by DOE and we plan to review this information in FY 89 to identify key safety and licensing concerns.

NRC has not reviewed the actinide burning potential of the LMRs since this has not been proposed to us by DOE. However, the provision of actinide burning capability would, in our view, require demonstration of satisfactory fuel performance and reactor physics characteristics with actinides present.

QUESTION 8. How do the different advanced reactors compare in the context of NRC's Advanced Reactor Policy Statement?

ANSWER.

The following advanced reactors appear to be consistent with the intent and with many of the attributes listed in the NRC's Advanced Reactor Policy Statement:

(1) MHTGR
(2) PRISM
(3) SAFR
(4) AP-600
(5) Small Boiling Water Reactor (SBWR)

However, the advanced LWRs (ABWR, RESAR SP/90, and CE System 80+) utilize and build upon more traditional LWR technology to reliably accomplish their safety functions. These are regarded as evolutionary and; therefore, are not considered advanced reactors as that term is used in the context of NRC's Advanced Reactor Policy Statement.

QUESTION 9. Are spent fuel skeletons classified as "greater than Class C waste?" If so, what is NRC's schedule for promulgating disposal requirements for such waste, and what interaction have you had with the Department of Energy concerning the disposition of such waste from the rod consolidation demonstration program?

ANSWER.

Hardware from fuel assembly consolidation operations (spent fuel "skeletons") may or may not contain radionuclides in concentrations that exceed the limits for Class C (GTCC) waste as specified in NRC's regulation, 10 CFR 61. Radionuclide content and concentrations in spent fuel skeletons vary depending on the skeleton material composition and the irradiation history of the fuel assembly.

We believe that there is no need to promulgate specific disposal requirements for GTCC waste. Rather, we believe that all GTCC waste should be disposed in a geologic high-level waste (HLW) repository. NRC has advised DOE that, in NRC's view, the very small volume of GTCC waste expected from all sources does not justify development of regulations for licensing a separate disposal facility. NRC regulations for disposal of waste in a geologic repository already exist as 10 CFR 60. We are willing to work with DOE to develop any additional licensing criteria (e.g., waste packaging requirements) that might be needed for disposal of GTCC waste in a geologic repository.

We understand that upon receipt of spent fuel assemblies from NRC licensees as provided for in the Nuclear Waste Policy Act, DOE plans to achieve greater disposal efficiency by consolidating the fuel assemblies into two streams, the fuel rods and the fuel skeletons. DOE has indicated that it plans to dispose of the skeletons with the spent fuel rods in the geologic HLW repository.

QUESTION 10. What is the status of NRC's review of the Advanced LWR?

ANSWER.

The Office of Nuclear Reactor Regulation is presently reviewing four standardization proposals relative to future large size advanced light water reactor (ALWR) plants. These are:

The Electric Power Research Institute (EPRI) ALWR Utility Requirements Document, which is a comprehensive statement of utility-generated requirements for design, construction and performance of ALWR power plants. Completion of the staff's safety evaluation is scheduled for January 1991.

The General Electric Company's application for a final design approval (FDA) and design certification of its Advanced Boiling Water Reactor (ABWR). Our decision on the FDA is scheduled for July 1990, and design certification in late 1991.

The Combustion Engineering application for a final design approval (FDA) and design certification of its Advanced Pressurized Water Reactor CESSAR System 80+. Our schedule calls for a decision on the FDA in December 1990 and design certification in late 1991.

The Westinghouse Electric Company's application for a preliminary design approval (PDA) for its Advanced Pressurized Water Reactor, RESAR SP/90.

Our schedule indicates a decision on the PDA by December 1988. However, Westinghouse has indicated that the PDA would be followed immediately by an application for an FDA and Design Certification. We have tentatively scheduled these for completion in the 1991-92 time frame.

Both General Electric and Westinghouse are in the process of developing mid-sized (600 MWe) passive plants (light water reactors). Westinghouse has requested that the NRC conduct a licensability review of its mid-sized design and plans to provide the conceptual design in early 1988. GE has not formally notified the NRC of its plans for licensing its mid-sized design.

QUESTION 11. How long is a design certification effective, and how long can it be extended?

ANSWER:

In the NRC's proposed criteria for design certification (10CFR52), a standard design certification would be valid for ten years from the date of issuance. Under this proposal, the holder of the design certification would be able to apply for renewal of the certification not less than twelve nor more than thirty-six months prior to expiration of the initial ten-year period, and the certified standard design could be renewed for not less than five nor more than ten years.

QUESTION 12. Would a design certification significantly reduce the licensing time for a new plant? Are there any foreseeable uncertainties that would make NRC change its mind between design certification and completion of plant construction?

ANSWER.

Yes, design certification can significantly reduce the time required to license a new plant. At the time a design certification is issued, the safety review would have been completed and the design subjected to the NRC's rulemaking process. Each new plant application that references the certified design would need only to address those areas of the design and the site interfaces not covered by rulemaking. Even greater time savings could be realized if the certified designs were used in conjunction with preapproved sites.

Although uncertainties will exist in any application for a construction permit or an operating license, these uncertainties can be reduced by referencing a certified design that is essentially complete in scope and level of design detail. Any foreseeable uncertainty would be dealt with during the design certification process.

It is the opinion of the NRC that, in order to achieve the maximum benefits from standardization, both NRC and industry changes to a certified design should be discouraged unless they are essential from the standpoint of safety. The threshold for changes to certified designs is spelled out in

10 CFR 50.109 and the proposed Nuclear Power Plant Standardization and Licensing Act of 1987 presently before Congress. Changes to certified designs will also be discussed in a new 10 CFR Part 52 being developed by the staff which addresses standardization and the standard plant certification process.

QUESTION 13. In your review of all the advanced reactor designs including LWR, HTGR and LMR, what is your general conclusion about nuclear plants in this country? Do you see the next generation reactors much more licensable? Do they have a good chance of reviving this nation's nuclear industry?

ANSWER:

The MHTGR, LMRs, and advanced LWR designs have the potential to generate electricity at a lower level of risk than currently operating nuclear power plants. However, additional R&D and safety testing will have to be performed by the applicant before the NRC can determine if the expected enhanced level of safety can be achieved. If the enhanced level of safety is confirmed, then it is reasonable to assume that these reactors will be more licensable than nuclear plants that have already been licensed.

The revival of the nuclear industry depends upon future decisions by the Congress, the DOE, the electric utility industry as well as the NRC. These decisions involve the extent to which the public and private sectors are willing to support development of these technologies, the cost of electric power generation from these technologies and confidence in their potential to protect the public, the environment and the plant investment. While the decisions from NRC are directed toward safety (and could cost) it is our view that all of the advanced designs can be made licensable and that their potential for acceptance by the electric utility industry depends primarily on the willingness of the public and private sector to invest sufficient funds to demonstrate the designs.

Mrs. LLOYD. The hearing will come to order.

We do apologize for the delays, but that is part of the Congressional process.

PANEL 1: SPACE NUCLEAR POWER SYSTEMS—U.S. DEPARTMENT OF DEFENSE

Mrs. LLOYD. Our next two witnesses also appear as a panel, Colonel George Hess, who is the Director of Survivability, Lethality and Key Technologies of the Strategic Defense Initiative Organization in the Department of Defense, and Colonel Joseph R. Johnson, who is Commander, Space Technology Center of the Air Force Systems Command.

Gentlemen, I do welcome you to the Subcommittee. Your written statements will be made a part of the record. You may summarize them as you present your testimony, and I believe that Colonel Hess will begin.

Thank you for being here and we do welcome you.

STATEMENT OF COL. GEORGE M. HESS, JR., DIRECTOR, SURVIVABILITY, LETHALITY, AND KEY TECHNOLOGIES, STRATEGIC DEFENSE INITIATIVE ORGANIZATION, U.S. DEPARTMENT OF DEFENSE, WASHINGTON, DC

Colonel HESS. Thank you, Madam Chairman.

I would like to take the opportunity to highlight some of the points out of the testimony and to answer some of the questions that have already been addressed.

I think everyone on this Committee recognizes that certain key requirements must be met by the power systems that support SDIO. They are highlighted in the upper-right-hand corner, there, not the least of which is affordable. Of course, survivability is a major driving issue on our power systems as well as reliability and compatibility with the rest of the systems.

Our functions in our space power program are indicated down here. We have essentially two different areas of concentration. In the baseload power.

[The information follows:]

SUMMARY OF PRIME POWER REQUIREMENTS FOR NEAR, MID, AND FAR TERM SDI ARCHITECTURES

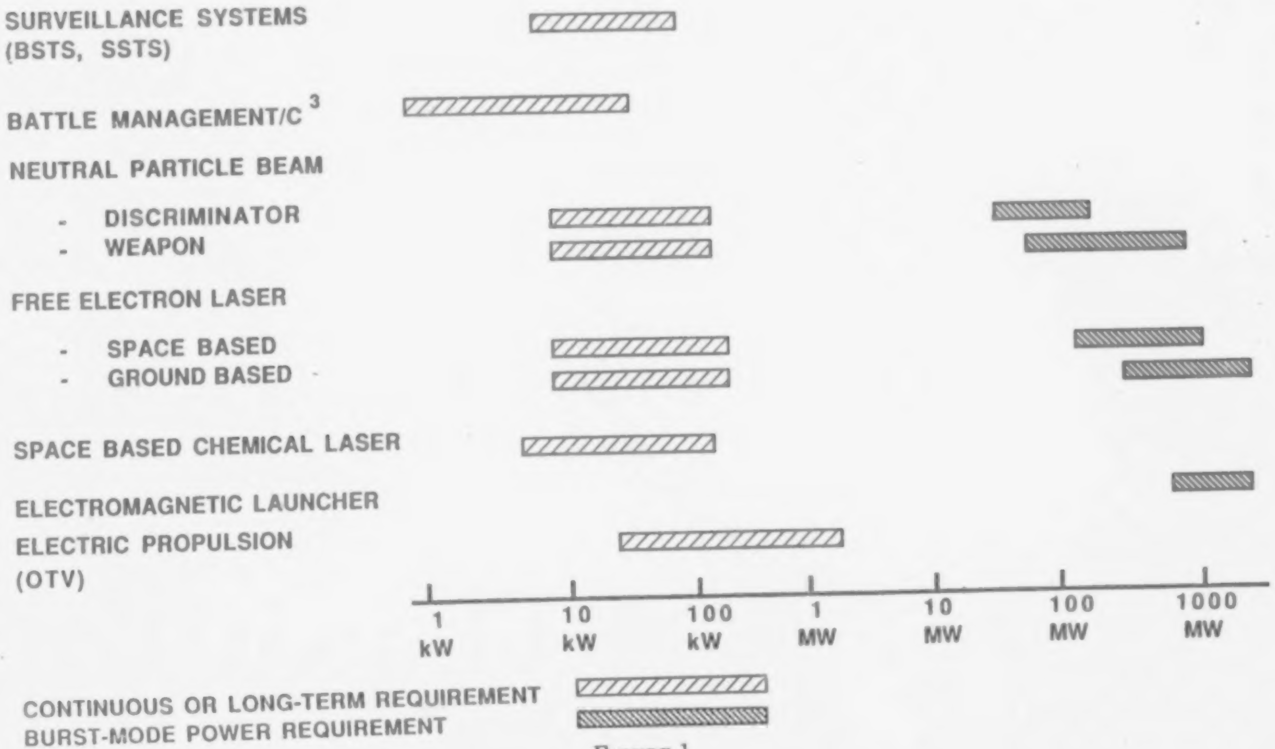


FIGURE 1

Mrs. **Lloyd**. Excuse me, Colonel, I think when you get some more lights off and perhaps close the door, so we can take advantage of your presentation.

Colonel **Hess**. Thank you.

In SDI, our functions are generally two broad areas: we have the requirement to supply what we call baseload power to sensors, for cryo, refrigerators for our sensor platforms for communications for the computation capability on board our systems, and these are generally in the tens to hundreds of kilowatts, perhaps in extreme systems, for sensor platforms, perhaps something like the space based radar, in a low multi-megawatt, and then a completely different category of systems, burst-mode power for the use in discrimination techniques for advanced directed energy applications and directed energy weapons.

Of course there is the associated ground-power needs for such things as free electron lasers and other applications as indicated on the viewgraph.

This is a more detailed assessment of our power requirements as a function of the type of systems that we may see developed particularly in Phase II of the SDI application, as opposed to the nearer term Phase I, which has received a lot of press recently.

The programs we are developing and how they apply against these requirements are indicated here. The SP–100 addresses that range that I indicated earlier, 10 to 100 plus kilowatts, perhaps up to a megawatt for sensors and things of that nature, housekeeping power.

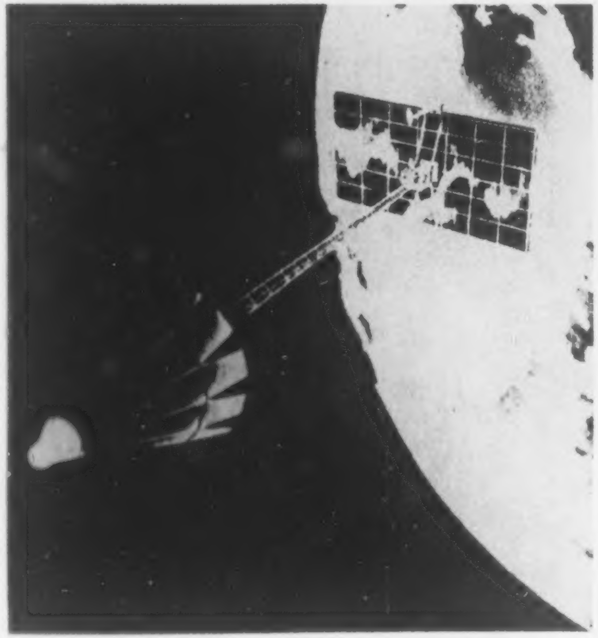
Then, the area in which we are clearly making technology breakthroughs, or require technology breakthroughs, and that is in the nuclear multi-megawatt area indicated on the right, where we need hundreds of megawatts of power in the burst mode, usually for shorter periods of time.

The technology drivers are important because they drive and identify the permissible activities that you can engage in. We have purposely stressed the large umbrella of survivability. There are many requirements there that are self-explanatory but I personally believe that the survivability requirements on advanced systems, particularly for the military, may be the single most important factor in driving us away from reliance on solar power systems into the and crossing the threshold into dependence upon nuclear power systems, and I will have more to say about that in a moment.

But all of these other considerations are things that go into the down selection process for the various power systems we are considering.

The advantages of nuclear power are indicated here. They are well known to the Committee. Mass reductions of two to five over high-powered alternatives, and that particular advantage increases as you get to extremely high-power systems. They are orientation independent; that is the issue of survivability. You do not have to worry about maintaining an orientation with respect to the sun. Also you do not have to worry about eclipses of the system by the moon and things of that nature. The increased hardening, you see that those second and third reasons are completely oriented toward the survivability issue of which I spoke. They are more compact and again the maneuverability issue, a survivability concern again, and the cost projections particularly for high-power systems are considerably less than their high-power solar alternatives.

SPACE NUCLEAR POWER SYSTEMS CHARACTERISTICS



ADVANTAGES

- MASS REDUCTIONS OF TWO TO FIVE OVER HIGH POWER ALTERNATIVES
- ORIENTATION INDEPENDENT
- CAN BE HARDENED TO INCREASINGLY TAXING SOVIET THREATS
- MORE COMPACT/MANEUVERABLE THAN ALTERNATIVES
- UNIT COSTS PROJECTED TO BE SIGNIFICANTLY LESS

DISADVANTAGES

- RESTRICTIONS ON MANNED MAINTENANCE
- ADDITIONAL SAFETY CONCERNS
- DEVELOPMENT COST HIGHER
- TIMELINESS

8-248

FIGURE 2

The disadvantages are indicated here. The safety concerns and the development costs, which I will address earlier and the timelines, and I think I will wait and have more to say about that in a moment.

We have ongoing programs. The SP–100 is the best known, 10 to 100 kilowatts. The system is currently baselined at 100-kilowatt power system. The important point here: it has moved from paper into hardware. We have started fuel pin fabrication at Las Alamos and the site preparation is ongoing at Hanford. So this program, once the dream of some visionaries in the 1983 time frame—1981 to 1983 time frame—has come to the point where the United States now has an active space nuclear power thrust which is in our minds, of course, long overdue.

We have also a thermionic fuel cell element development program that has had very good test results to date. The primary rationale behind the selection of thermo-electrics for the SP–100 was concern about the reliability and the long-term life characteristic of thermionic fuel elements.

In order to address this problem, we started a thermionic fuel element verification program which has demonstrated that with advanced production and quality control techniques, that we can get emitters that have reasonable lifetimes.

The nuclear multi-megawatt program has moved beyond paper studies, and we now have six contractors selected for concept definition activities.

As I have indicated earlier, nuclear power is clearly the right answer for very high total power systems. Unfortunately, there are some acknowledged problems with what we believe to be the very right answer, and that is, of course, and recognized by all here, the extra-long gestation period and the development cost associated with this kind of system.

There is also what is commonly referred to as some social baggage associated with trying to get a program manager to accept a nuclear power system in his system. There are many missions that have been talked about by both NASA and the Department of Defense. In the non-SDI world, there is clearly renewed interest in nuclear power systems to power such things as Air Force space-based radars. The problem is, again, to get acceptance that this is the right solution, and we believe very strongly, and a realization that has solidified in our mind that we are going to have to fly a reference mission as part of the development process in order to get acceptance of this by the community, not only in the DOD but in NASA.

My colleagues in the development community in the Air Force, the program managers at Space Division and the like are not going to accept nuclear power as a reality, not only for the reason of technical feasibility, which I think we can clearly establish, but for the rationale that we have got to demonstrate that we can get through the bureaucracy in a timely and efficient manner, and that these program managers do not face the prospect of months and months of delay as the system decides whether or not the flight test is going to be acceptable.

So we are putting increased emphasis on the fact that we believe that a reference mission is going to be part of the cost of doing business in this area to demonstrate that this technology is ready to fly.

The referenced mission was asked about earlier by Mr. Morrison. This is, as I indicated, a vital step toward demonstrating the readiness and the social acceptability of nuclear reactors in space.

We have tentatively linked the SP-100, as was indicated earlier, with an electric-propulsion subsystem, most probably an electric-arcjet, to demonstrate not only that the reactor is ready to fly, but a secondary mission of demonstrating electric propulsion availability.

The planning for this experiment envisions now a flight test in the mid-1990's. It will be defined as part of the on-going operations of SP-100. There will be a heavy concentration on the safety issues. And it will be a mechanism, as I indicated, for testing arc-jet technologies for both maneuver and orbit transfer, much along the lines as outlined by the witness from the NASA.

Here is one concept to indicate that we have some depth at this point in time behind the definition of the system. The reactor and the cooling system are out there in front. A satellite with an arc jet on it that would be maneuvered in a nuclear-safe orbit to demonstrate to potential users that this technology is ready for serious application.

It's always appropriate to discuss the safety aspects. I would have to agree with earlier witnesses that the safety concerns cannot be over-emphasized in the public mind.

We have initiated studies on the possibility of permanent disposal of nuclear power systems in orbit. While we intend to place all of our systems in nuclear-safe orbits, there is a possibility always of that one-in-a-million chance that these things could come down. And we would like to avoid any possibility of reentry, and permanent disposal in possibly flying these things into the sun.

This would involve robotic systems, launched at the end of life, rendezvousing with these systems, and flying these missions into deep space where they could never again possibly—You know. Remove any possibility of ever returning to earth. And we have discussed the possibility.

Senator Bennett Johnston attended one of our sessions on nuclear power in Albuquerque and discussed the possibility that, as has been noted, since we are not the only nation involved in space nuclear power, the possibility was discussed at that symposium of cooperative programs to address the issue of flight safety and to ensure that incidents like Cosmos 954, I believe it was, do not happen again.

As you are aware, we have a very effective joint program with the Department of Energy in this area. They are heading up the actual activity in reactor development, as is required and very appropriate, on the reactor development. It makes effective use of the resources and expertise of both agencies. It maximizes the expertise, as I indicated.

NASA is, again, as you are aware, a full partner in the development of SP-100 technology because of their renewed interest in space nuclear reactor technology.

And, of course, we continue to be, within SDIO, advocates of investment now in this very necessary technology. This is a clear case of where we are looking beyond the Phase I systems, because power is a pacing item for many of the phase two missions.

There is clearly a need to invest now because in reality there is no crash development programs in the nuclear business. We are operating on the edge of technology in many areas of materials and other areas. The development programs are, at times, very lengthy. And the analysis and the safety analyses and tests are very time-consuming. It all results in a long gestation period for these systems.

Summarizing, we believe that nuclear power is the right answer for many SDIO missions. The users are going to require that we have not only validated the technology. And, again, I stress the fact that we have a predictable approval process that they can count on, that a review process is predictable, and has a certain cost associated with it.

And I think that the flight demonstration that is indicated here is going to be necessary to demonstrate to these prospective program managers that this process can be handled expeditiously and at a reasonable cost. We are looking at, again, a safety issue concern with permanent disposal. Possible international participation or international programs in this area have been thought of and we are investigating.

And we need to invest now and maintain the momentum that is represented in the hardware that's being developed for SP-100. And joint programs between NASA, DOE, and DOD remain, in our opinion, the most effective way to meet these requirements.

This concludes my remarks. If there is any time for questions, I'll be happy to answer them.

[The prepared statement of Colonel Hess follows:]

STATEMENT ON

THE STRATEGIC DEFENSE INITIATIVE SPACE POWER DEVELOPMENT POLICY

BY

COLONEL GEORGE M. HESS, JR.

DIRECTOR, SURVIVABILITY, LETHALITY & KEY TECHNOLOGIES

STRATEGIC DEFENSE INITIATIVE ORGANIZATION

BEFORE THE

SUBCOMMITTEE ON ENERGY RESEARCH & PRODUCTION

COMMITTEE ON SCIENCE & TECHNOLOGY

HOUSE OF REPRESENTATIVES

MARCH 16, 1988

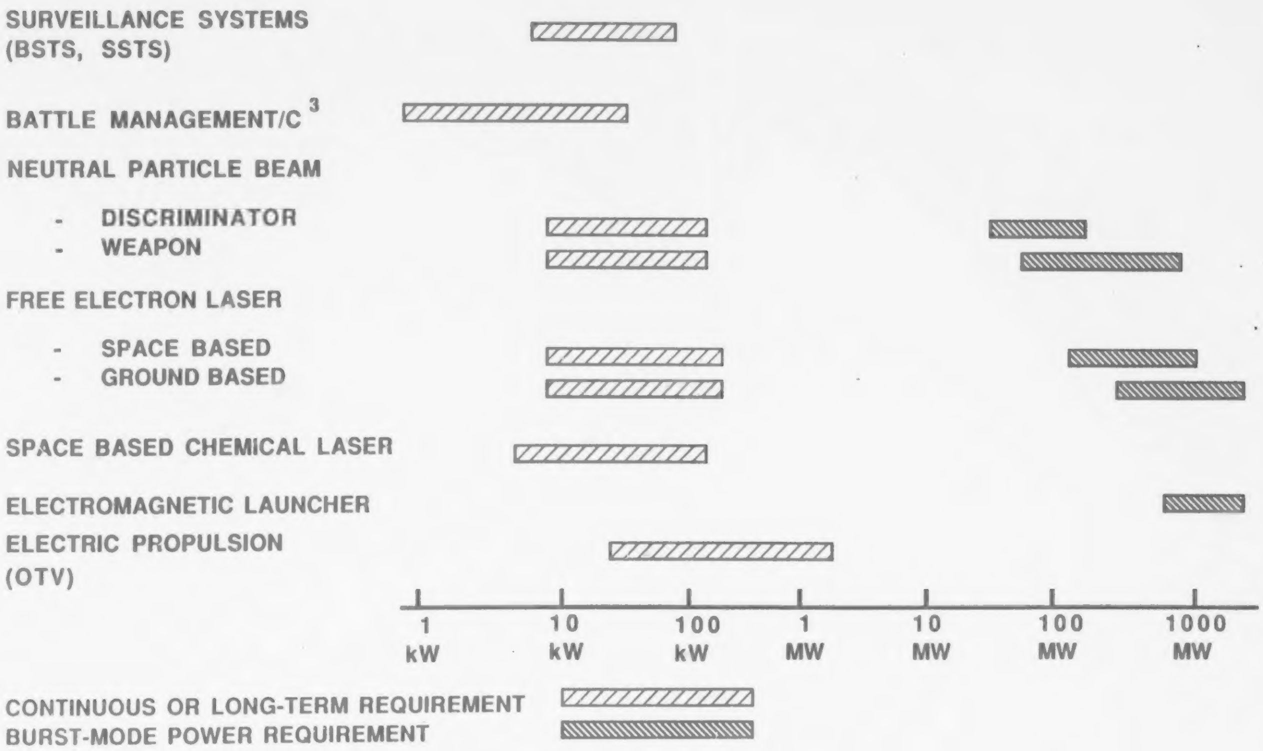
THANK YOU MADAM CHAIRMAN, FOR THE OPPORTUNITY TO TESTIFY BEFORE YOUR SUBCOMMITTEE TODAY. I AM COLONEL GEORGE HESS, DIRECTOR OF THE SURVIVABILITY, LETHALITY AND KEY TECHNOLOGIES (SLKT) OFFICE OF THE STRATEGIC DEFENSE INITIATIVE ORGANIZATION (SDIO). MY OFFICE IS RESPONSIBLE FOR SDI'S MAINLINE POWER DEVELOPMENT EFFORTS. THE FOCUS OF MY REMARKS TODAY WILL BE UPON THE NUCLEAR POWER TECHNOLOGIES WE ARE DEVELOPING IN CONJUNCTION WITH BOTH THE DEPARTMENT OF ENERGY AND THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION TO MEET THE PROJECTED NEEDS OF THE STRATEGIC DEFENSE INITIATIVE.

AS I HAVE STATED IN PREVIOUS TESTIMONY BEFORE THIS COMMITTEE, THE SUCCESS OF NEARLY ALL ELEMENTS OF SDI IS CRITICALLY DEPENDENT UPON MAJOR ADVANCES IN THE AREA OF POWER AND POWER CONDITIONING. ADVANCED SPACE-BASED SYSTEMS FOR DEFENSE AGAINST BALLISTIC MISSILES WILL REQUIRE ELECTRICAL POWER OF TRULY UNPRECEDENTED LEVELS AND CHARACTERISTICS. THESE POWER AND VOLTAGE LEVELS AND TOTAL ENERGY REQUIREMENTS EXCEED OUR PRESENT EXPERIENCE IN SPACE-BASED SYSTEMS BY ORDERS OF MAGNITUDE. SOURCES CAPABLE OF GENERATING THE NECESSARY POWER MUST ALSO OPERATE WITH EXTREMELY HIGH LEVELS OF RELIABILITY WHILE CONCURRENTLY MEETING SEVERE CONSTRAINTS RELATIVE TO SIZE, MASS, LIFE-CYCLE COST AND SURVIVABILITY. FOR THE SPACE BASED NEUTRAL PARTICLE BEAM (NPB) AND FREE ELECTRON LASER (FEL) OVER ONE-HALF OF THE TOTAL PLATFORM MASS AND COST IS CHARGEABLE TO PROVIDING THE NECESSARY POWER. CLEARLY, THE SIGNIFICANT CHALLENGES ASSOCIATED WITH THE DEVELOPMENT OF POWER TECHNOLOGY FOR SPACE-BORNE SYSTEMS MUST BE MET IF THE POTENTIAL OF SDI SECOND GENERATION SYSTEMS ARE TO BE REALIZED.

POWER REQUIREMENTS ARE DEPENDENT ON SPECIFIC ARCHITECTURES, INCLUDING PARAMETERS SUCH AS TYPE AND NUMBER OF PLATFORMS, ALTITUDES, LETHALITY, TARGETS PER PLATFORM AND TIME-ON-TARGET TO NAME A FEW. ALTHOUGH PRECISE NUMBERS ARE STILL EVOLVING, THE CURRENTLY PROJECTED MISSION REQUIREMENTS FOR SDI SPACE-BASED SYSTEMS SHOW THERE ARE THREE MAJOR CATEGORIES OF POWER REQUIREMENTS. THEY ARE: (1) BASELOAD POWER AT THE FEW KILOWATT TO FEW HUNDRED KILOWATT LEVEL TO MAINTAIN PLATFORM SYSTEMS FUNCTIONS SUCH AS COMMUNICATIONS, SURVEILLANCE, ACQUISITION, TRACKING AND CRYOGENICS STORAGE CONTINOUSLY FOR YEARS: (2) ALERT LEVEL POWER IN THE RANGE OF ONE TO TEN MEGAWATTS TO ENABLE WEAPON "INSTANT ON" BATTLE READINESS CAPABILITY: AND, (3) BURST MODE POWER REQUIRING TENS TO HUNDREDS OF MEGAWATTS FOR HUNDREDS OF SECONDS TO POWER THE WEAPONS OR NPB DISCRIMINATION SYSTEMS NOW ENVISIONED. DURING THE PAST YEAR THREE AEROSPACE INDUSTRY TEAMS COMPLETED SPACE POWER ARCHITECTURE STUDIES UNDER AIR FORCE AUSPICES WHICH CONFIRMED THESE CATEGORIES OF POWER DEMANDS. NO PRESENTLY EXISTING SYSTEMS, COMPONENTS, OR DEVICES EVEN APPROACH THE ABILITY TO SATISFY THIS SPECTRUM OF REQUIREMENTS.

IN GENERAL ABRAHAMSON'S LETTER TO YOU DATED 12 JANUARY, 1988 AND IN TESTIMONY BEFORE THIS SUBCOMMITTEE LAST YEAR, WE HAVE STATED THAT THE DEVELOPMENT OF SPACE NUCLEAR TECHNOLOGY IS ESSENTIAL IN ORDER TO MEET SDI POWER NEEDS. FIGURE 1. SHOWS OUR CURRENT PROJECTIONS FOR GROWTH OF SPACE POWER REQUIREMENTS. BASELOAD POWER REQUIREMENTS ARE DETERMINED BY PLATFORM SPECIFIC SUBSYSTEMS SUCH AS CRYO-REFRIGERATORS FOR SENSORS AND LONG TERM CRYOGENIC FLUID STORAGE DEMANDING UP TO 100 KW; AND SURVIVABLE

SUMMARY OF PRIME POWER REQUIREMENTS FOR NEAR, MID, AND FAR TERM SDI ARCHITECTURES

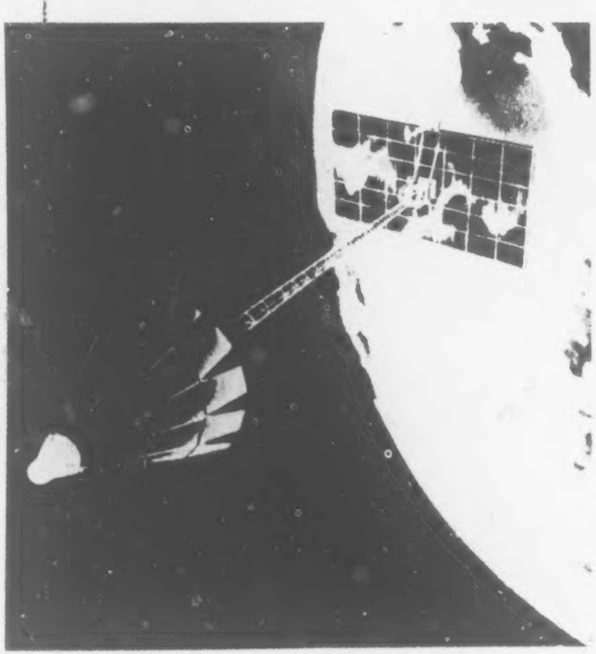


COMMUNICATIONS WHICH COULD NEED MORE THAN 30 KW. A SPACE BASED RADAR SYSTEM POTENTIALLY REQUIRES MORE THAN 100 KW.

OUR CONTINUING EMPHASIS ON DEVELOPMENT OF SPACE NUCLEAR POWER IS CAUSED BY ITS ATTRIBUTES OF HIGH SURVIVABILITY, COMPATIBILITY WITH SPACECRAFT REQUIREMENTS SUCH AS MANEUVERING AND UNSURPASSED TOTAL ENERGY CAPACITY. NUCLEAR REACTOR POWER PLANTS ARE INHERENTLY HIGHLY RESISTANT TO THERMAL, KINETIC AND RADIATION THREATS BOTH FROM THE NATURAL ENVIRONMENT OF SPACE AND FROM HOSTILE ACTIONS. THE SP-100 WILL SUPPLY BASELOAD POWER FOR SEVEN TO TEN YEARS OF UNATTENDED OPERATION. ITS COMPACT AND RUGGED DESIGN, PASSIVE POWER CONVERSION AND CLOSED LOOP CONFIGURATION ENSURE SPACE PLATFORM COMPATIBILITY. OUR STUDIES INDICATE THAT MULTIMEGAWATT BURST POWER SUBSYSTEMS USING NUCLEAR REACTORS ARE MORE COMPATIBLE WITH WEAPON PLATFORMS BECAUSE THE HYDROGEN EFFLUENT HAS LESS IMPACT ON THE WEAPON AND SENSOR OPERATIONAL ENVIRONMENT THAN OTHER POSSIBLE EFFLUENTS. IN ADDITION, THE HIGH SPECIFIC ENERGY AVAILABLE FROM NUCLEAR REACTORS IS IMPORTANT TO MEET THE REQUIREMENT OF FREQUENT FULL POWER SYSTEM TESTS TO VERIFY SYSTEM READINESS, SHOULD THIS BECOME NECESSARY.

SOME OF THESE CHARACTERISTICS ARE SUMMARIZED IN FIGURE 2., WHICH ALSO POINTS OUT ADVANTAGES IN SYSTEM MASS AND LOWER PROJECTED UNIT COSTS. WE RECOGNIZE THE ADDITIONAL SAFETY CONCERNS, HIGHER DEVELOPMENT COST AND EXTENDED DEVELOPMENT TIME NECESSARY IN NUCLEAR TECHNOLOGY; BUT THE BENEFITS CLEARLY OUTWEIGH THE DISADVANTAGES.

SPACE NUCLEAR POWER SYSTEMS CHARACTERISTICS



ADVANTAGES

- MASS REDUCTIONS OF TWO TO FIVE OVER HIGH POWER ALTERNATIVES
- ORIENTATION INDEPENDENT
- CAN BE HARDENED TO INCREASINGLY TAXING SOVIET THREATS
- MORE COMPACT/MANEUVERABLE THAN ALTERNATIVES
- UNIT COSTS PROJECTED TO BE SIGNIFICANTLY LESS

DISADVANTAGES

- RESTRICTIONS ON MANNED MAINTENANCE
- ADDITIONAL SAFETY CONCERNS
- DEVELOPMENT COST HIGHER
- TIMELINESS

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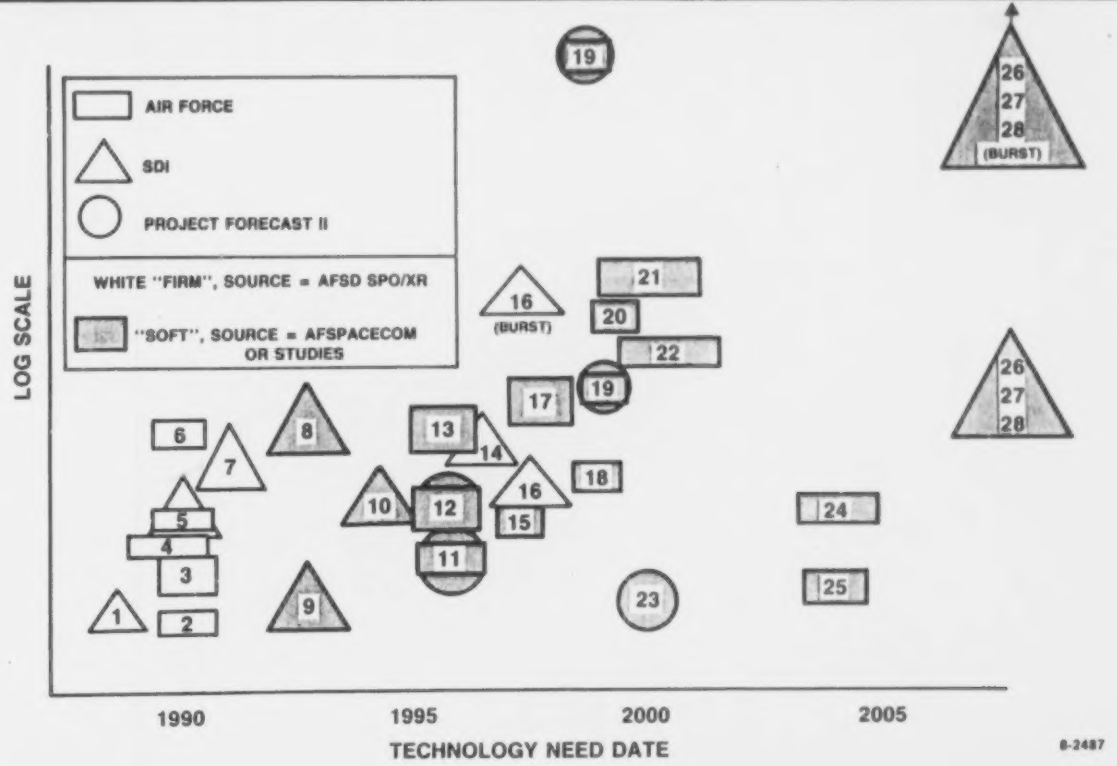
AS YOU KNOW, NUCLEAR TECHNOLOGY PROGRAMS AIMED AT SATISFYING SDI NEEDS ARE BEING CARRIED OUT BY SDIO IN CONJUNCTION WITH DOE, NASA AND OTHER AGENCIES. THESE POWER PROGRAMS ARE NOW IN FULL OPERATION AND MAKING RAPID PROGRESS TOWARD THE GOALS OF IDENTIFYING THE MOST ATTRACTIVE POWER SYSTEM CONCEPTS AND ESTABLISHING A TECHNOLOGY BASE CRITICAL TO THEIR DEVELOPMENT AND DEMONSTRATION. THE GOALS WILL BE MET THROUGH TECHNOLOGY ADVANCEMENTS WHICH WILL BE EMBODIED INTO PROOF OF PRINCIPLE TESTS ON CRITICAL POWER SOURCE AND CONDITIONING COMPONENTS. FEASIBILITY WILL BE DEMONSTRATED BY APPROPRIATE GROUND ENGINEERING SYSTEM DEMONSTRATIONS WHICH WILL ENGENDER HIGH CONFIDENCE IN THE PERFORMANCE AND RELIABILITY OF FLIGHT SYSTEMS.

THE SP-100 PROGRAM HAS ACHIEVED MAJOR ADVANCES RECENTLY. LIFE TESTING OF FUEL HAS THUS FAR DEMONSTRATED THE EQUIVALENT OF FIVE YEARS FULL POWER OPERATION WITH NO SIGNIFICANT DEGRADATION. TESTING CONTINUES WITH HIGH CONFIDENCE THAT SEVEN TO TEN YEAR FULL POWER PERFORMANCE WILL BE VERIFIED. THE IMPORTANT DESIGN FEATURES OF THE THERMOELECTRIC CONVERTER MODULES HAVE BEEN CONFIRMED BY TESTING UNDER OPERATING CONDITIONS. AN IMPORTANT MILESTONE WAS MET WHEN THE LOS ALAMOS FUEL FABRICATION FACILITY WAS FORMALLY QUALIFIED AND PRODUCTION OF FUEL PINS FOR THE DEMONSTRATION REACTOR GOT UNDERWAY.

TO ENSURE RESPONSIVENESS TO EVOLVING REQUIREMENTS, THE PROGRAM IS CLOSELY COUPLED TO WEAPONS SYSTEMS DEVELOPMENT EFFORTS UNDERWAY WITHIN SDIO. THE RESULTING INSIGHTS INTO POWER NEEDS ARE ILLUSTRATED IN FIGURE 3 WHICH DEPICTS AN UNCLASSIFIED SUMMARY OF SOME ANTICIPATED SDI AND AIR FORCE SPACE POWER APPLICATIONS. IT IS NOTEWORTHY THAT THE AIR FORCE PROJECTED NEEDS FOR

(U) SPECTRUM OF POWER REQUIREMENTS



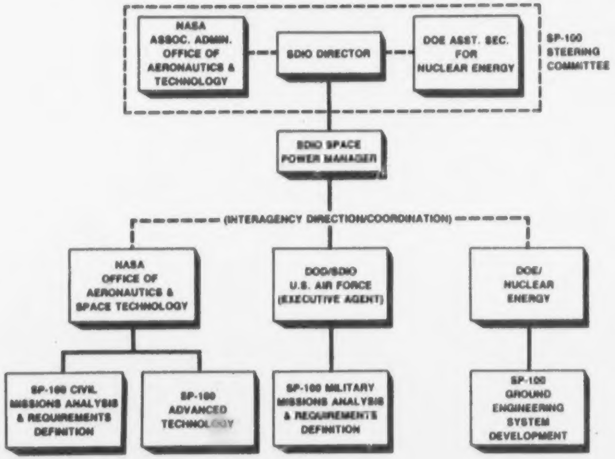
POWER COINCIDE WITH AND OVERLAP SDI REQUIREMENTS EXCEPT FOR THE BURST REQUIREMENT.

THE SP-100 IS BEING DEVELOPED BY A JOINT ORGANIZATION COMPRISING SDIO, DOE AND NASA. CONSISTANT WITH ITS CHARTER, DOE HAS THE RESPONSIBILITY OF MANAGING THE DEVELOPMENT OF NUCLEAR POWER TECHNOLOGY. NASA HAS CIVIL SPACE EXPLORATION APPLICATIONS FOR SPACE NUCLEAR POWER REACTOR SOURCES OF THE SP-100 CLASS AND PROVIDES EXPERTISE ON THE POWER CONVERSION SYSTEMS FOR GROWTH CAPABILITY AND OPERATING CONDITIONS FOR THE SP-100. ALL THREE ORGANIZATIONS PARTICIPATE IN FUNDING AND MANAGEMENT OF THE PROGRAM. FIGURE 4. DEPICTS THE SP-100 PROGRAM ORGANIZATION.

DESPITE RECENT STRINGENT SDIO BUDGET CONSTRAINTS, THE CONTINUITY OF DOE SUPPORT AND RECENT INCREASES IN NASA FUNDING HAVE ENABLED THE SP-100 GROUND ENGINEERING SYSTEM AND ITS SUPPORTING TECHNOLOGY PROGRAMS TO MAINTAIN PROGRESS ALTHOUGH SOME ELEMENTS HAVE SLIPPED INTO THE FLIGHT ENGINEERING PHASE AND REACTOR TESTS HAVE SLIPPED INTO FY 1992. AS THE SP-100 MOVES INTO THE HARDWARE PHASES OF THE DEVELOPMENT PROGRAM IT BECOMES ABSOLUTELY ESSENTIAL THAT CONTINUITY OF ALL FUNDING BE ASSURED IN ORDER TO MEET SDI GOALS FOR SPACE APPLICATIONS. IF A DECISION IS MADE TO PROCEED WITH A PHASED STRATEGIC DEFENSE DEPLOYMENT, THE REQUIRED DEVELOPMENT SCHEDULES FOR THE NECESSARY POWER SYSTEMS BECOME VERY TIGHT. ALTHOUGH DEPLOYMENT OF INITIAL SDI SYSTEMS MAY BE POSSIBLE WITHOUT SPACE REACTORS, FUTURE DEPLOYMENT SCHEDULES WILL REQUIRE AGRESSIVE PURSUIT OF PRESENT SCHEDULES FOR REACTOR DEVELOPMENT. FOR EXAMPLE, SP-100 IS REQUIRED TO POWER MANY OF THE HIGH POWERED SENSOR OPTIONS BEING CONSIDERED FOR SECOND GENERATION SYSTEMS.

REASONS FOR JOINT PROGRAMS

SP-100 PHASE II MANAGEMENT STRUCTURE


NASA ASSOC. ADMIN. OFFICE OF AERONAUTICS & TECHNOLOGY
SDIO DIRECTOR
DOE ASST. SEC. FOR NUCLEAR ENERGY
SP-100 STEERING COMMITTEE
SDIO SPACE POWER MANAGER
(INTERAGENCY DIRECTION/COORDINATION)
NASA OFFICE OF AERONAUTICS & SPACE TECHNOLOGY
DOD/SDIO U.S. AIR FORCE (EXECUTIVE AGENT)
DOE/ NUCLEAR ENERGY
SP-100 CIVIL MISSIONS ANALYSIS & REQUIREMENTS DEFINITION
SP-100 ADVANCED TECHNOLOGY
SP-100 MILITARY MISSIONS ANALYSIS & REQUIREMENTS DEFINITION
SP-100 GROUND ENGINEERING SYSTEM DEVELOPMENT

- COMMON TECHNOLOGY NEEDS OF DOD AND NASA
- COST EFFECTIVE USE OF RESOURCES
- HIGH DEVELOPMENT COSTS STRAINS INDIVIDUAL BUDGETS
- MAXIMIZES USE OF INDIVIDUAL AGENCIES EXPERTISE

— REACTOR DEVELOPMENT (DOE)

— AEROSPACE SUBSYSTEM (NASA)

— SPACECRAFT INTEGRATION (DOD/NASA)

FURTHERMORE, SP-100 COUPLED WITH A REGENERATIVE FUEL CELL, OFFERS THE ONLY LONG LIFE POWER SOURCE ABLE TO SUPPORT AN NPB DISCRIMINATION SYSTEM REQUIRING A FEW TENS OF MEGAWATTS.

IN THE MULTIMEGAWATT AREA, BOTH NUCLEAR AND NON-NUCLEAR POWER SOURCES ARE BEING CONSIDERED TO SUPPLY BURST POWER FOR WEAPONS SYSTEMS APPLICATIONS. AS I MENTIONED BEFORE, THE ISSUE OF EFFLUENT INTERACTION WITH THE WEAPON AND PLATFORM SUBSYSTEMS MAKES THE NUCLEAR OPTION ATTRACTIVE, AND NUCLEAR CONCEPTS AND ASSOCIATED TECHNOLOGIES ARE BEING VIGOROUSLY PURSUED UNDER DOE TECHNICAL LEADERSHIP. AS A RESULT OF A RECENT PROCUREMENT ACTION, SIX INDUSTRY TEAMS ARE STARTING COMPETITIVE CONCEPTUAL DESIGN AND TRADE STUDIES WITH A DOWN SELECTION SCHEDULED IN FY 1989. THIS PROGRAM, WHICH IS CO-FUNDED BY DOE, WILL THEN FOCUS ITS EFFORTS ON DETAILED DESIGN STUDIES AND SUPPORTING TECHNOLOGY DEVELOPMENT FOR THE SURVIVING CONCEPTS. THE ULTIMATE GOAL IS TO ESTABLISH AT LEAST ONE CONCEPT BY FY 1992 FOR FURTHER DEVELOPMENT AND APPROPRIATE GROUND DEMONSTRATION IN THE MID-90'S TIME FRAME.

I HAVE NOTED THAT OUR PRESENT PACE OF DEVELOPMENT PROGRAMS FOR BOTH BASELOAD AND BURST NUCLEAR REACTOR POWER SYSTEMS MUST BE SUSTAINED IN ORDER TO HAVE QUALIFIED DESIGNS AVAILABLE IN TIME TO MEET PROJECTED SPACE SYSTEM DEPLOYMENT SCHEDULES. IT IS APPROPRIATE TO ADDRESS THE SAFETY CONSIDERATIONS INVOLVED IN OPERATIONAL DEPLOYMENT OF NUCLEAR SPACE POWER SOURCES. SAFETY ASPECTS PLAY A PREDOMINANT ROLE IN SPACE NUCLEAR REACTOR POWER SYSTEM DESIGN AND DEVELOPMENT BECAUSE ULTIMATE DEPLOYMENT OF THESE ESSENTIAL SYSTEM ELEMENTS WILL DEPEND UPON PUBLIC PERCEPTION THAT THEY ARE SAFE. AS A RESULT,WE HAVE PLACED MAJOR EMPHASIS ON ALL SAFETY ASPECTS OF

REACTOR MANUFACTURE, TRANSPORTATION, INSTALLATION, LAUNCH, OPERATION AND END OF LIFE DISPOSITION.

SAFETY CONSIDERATIONS DICTATE THAT SPACE NUCLEAR REACTORS BE HANDLED AND LAUNCHED IN AN INERT CONDITION SUCH THAT NO CONCEIVABLE GROUND OR LAUNCH INCIDENT COULD RESULT IN DISPERSION OF RADIOACTIVE MATERIALS. THE REACTOR CAN ONLY BE ACTIVATED WHEN IN OPERATIONAL ORBIT AND, AT END OF SERVICE LIFE, MEASURES WILL BE TAKEN TO KEEP THE REACTOR IN A STABLE ORBIT. IN THE EXTREMELY UNLIKELY EVENT THAT THE SPENT REACTOR SHOULD ACCIDENTALLY BE INDUCED TO REENTER THE ATMOSPHERE, POSITIVE DESIGN FEATURES WILL PREVENT ANY RELEASE OF RADIOACTIVE MATERIALS. INDEPENDANT SAFETY REVIEW BOARDS ARE ACTIVELY OVERSEEING THESE IMPORTANT DESIGN AND OPERATIONAL CRITERIA.

IN ADDITION TO THIS COMPREHENSIVE APPROACH TO OPERATIONAL SAFETY, STUDIES HAVE BEEN INSTITUTED TO EXAMINE MEASURES WHICH COULD BE TAKEN IN A SITUATION WHERE, FOR SOME UNFORSEEN REASON, A REACTOR WERE TO LEAVE A STABLE ORBIT. ROBOTIC MEANS MIGHT BE USED TO RENDEZVOUS WITH THE REACTOR IN ORBIT AND DISPOSE OF IT TO SPACE LOCATIONS WHICH WOULD PERMANENTLY PRECLUDE EARTH REENTRY. THE DESIRABILITY AND FEASIBILITY OF INTERNATIONAL COLLABORATION IN THIS AREA WITH OTHER NATIONS OPERATING OR PLANNING SPACE NUCLEAR POWER SOURCES HAS BEEN THE SUBJECT OF PRELIMINARY DISCUSSIONS WITH DOE, NASA, AND THIS SUBCOMMITTEE.

AS THE SP-100 PROGRAM EVOLVES INTO THE FIRST HARDWARE PHASES OF DEVELOPMENT, THE PLANNING AND PREPARATION FOR FLIGHT DEMONSTATION HAVE BEEN

PROCEEDING WITH THE ACTIVE PARTICIPATION OF THE AIR FORCE. AN ARCJET ELECTRIC PROPULSION UNIT IS PLANNED TO BE POWERED BY AN SP-100 NUCLEAR POWER SOURCE IN AN ORBITAL FLIGHT EXPERIMENT TO BE CONDUCTED IN THE MID-90'S. TWO AEROSPACE INDUSTRY STUDY TEAMS WILL BE SELECTED TO DEVELOP FLIGHT TEST PLANS AND CONCEPTUAL DESIGNS FOR THE EXPERIMENTAL SPACECRAFT. AN EXTREMELY IMPORTANT PART OF THE PLANNED FLIGHT EXPERIMENT WILL BE THE ESTABLISHMENT OF THE NECESSARY SAFETY APPROVALS AND PRECEDENTS WHICH WILL FACILITATE THE PLANNING OF SUBSEQUENT MISSIONS. A SECONDARY BUT PERHAPS EQUALY IMPORTANT DIVIDEND FROM THIS FLIGHT WILL BE THE DEMONSTRATION TO PERSPECTIVE SPACE SYSTEM PROGRAM MANAGERS THAT FLIGHT APPROVAL AND EXECUTION CAN BE REALIZED ON A TIMELY AND PREDICTABLE BASIS. THE FLIGHT DEMONSTRATION WILL VERIFY ON-ORBIT OPERATION OF A SPACE QUALIFIED SP-100 SYSTEM; DEMONSTRATE ORBIT TRANSFER CAPABILITY USING ELECTRIC PROPULSION; AND DEMONSTRATE MANEUVERABILITY OF AN ORBITING SPACECRAFT TO ENHANCE ITS OPERATION AND SURVIVABILITY. IN THIS CONNECTION, CALCULATIONS SHOW THAT USE OF ELECTRIC PROPULSION IN DEPLOYMENT OF SDI CONSTELLATIONS CAN SIGNIFICANTLY REDUCE THE TOTAL WEIGHT WHICH MUST BE LAUNCHED, AND CAN EVEN EFFECT SAVINGS IN TOTAL TIME REQUIRED FOR DEPLOYMENT. HERE AGAIN THERE IS SYNERGISM WITH NASA REQUIREMENTS, SINCE ELECTRIC PROPULSION IS A LEADING CONTENDER FOR THE PATHFINDER MARS FREIGHTER PROPULSION SYSTEM.

ANOTHER MAJOR THRUST IN OUR PROGRAM IS RESEARCH AND DEVELOPMENT IN PULSE POWER AND POWER CONDITIONING. THIS WILL PROVIDE THOSE DEVICES AND COMPONENTS NEEDED TO MATCH THE ELECTRICAL CHARACTERISTICS OF THE POWER SOURCE WITH THOSE REQUIRED BY THE LOAD. OUR EFFORTS ARE FOCUSSED IN SELECTED TECHNOLOGY AREAS WHICH INCLUDE ENERGY STORAGE, HIGH POWER

SWITCHING, DC TO DC VOLTAGE CONVERSION AND RADIO FREQUENCY SOURCES. IN MANY INSTANCES, ORDERS OF MAGNITUDE IMPROVEMENT IN CAPABILITY BEYOND THE PRESENT STATE OF THE ART WILL BE REQUIRED FOR OUR SYSTEMS.

I WOULD LIKE TO TAKE A MOMENT TO TELL YOU ABOUT A RECENT TECHNICAL ACCOMPLISHMENT IN THIS AREA. THE KEY TO THE DEVELOPMENT OF ADVANCED CAPACITORS FOR ENERGY STORAGE APPLICATIONS IS NEW HIGH QUALITY POLYMER FILMS HAVING SIGNIFICANTLY IMPROVED ELECTRICAL CHARACTERISTICS. UNTIL RECENTLY, THE BEST FILMS OF THIS TYPE WERE PRODUCED ONLY IN JAPAN. AS THE RESULT OF OUR RESEARCH PROGRAM, WE HAVE BEEN SUCCESSFUL IN DEVELOPING HERE IN THE UNITED STATES POLYMER FILM FORMULATION AND MANUFACTURING PROCESSES WHICH ARE CAPABLE OF PRODUCING THE HIGHEST PERFORMANCE CAPACITOR GRADE FILMS IN THE WORLD. THE SIGNIFICANCE OF THIS BREAKTHROUGH TRANSCENDS OUR DOD INTERESTS BECAUSE THE ENORMOUS NUMBERS OF COMMERCIAL CAPACITORS PRODUCED EACH YEAR FOR MEDICAL, INDUSTRIAL AND UTILITY ELECTRIC AND ELECTRONIC APPLICATIONS CAN NOW BE MANUFACTURED USING AMERICAN MADE FILMS. THE IMPROVED CHARACTERISTICS OF THE FILMS PERMIT SMALLER, LIGHTER AND MORE EFFICIENT CAPACITORS FOR CRITICAL MILITARY AND CIVIL AIR AND SPACE APPLICATIONS. THIS IS ANOTHER EXAMPLE OF SDI SUPPORTED RESEARCH WHICH IS HELPING TO RESTORE AND MAINTAIN OUR NATION'S TECHNICAL LEADERSHIP.

RECENT STRINGENT BUDGET CONSTRAINTS HAVE CAUSED US TO RESTUDY OUR FUNDING PROJECTIONS TO ENSURE THAT ONLY CRITICAL PROGRAM ELEMENTS ARE BEING SUPPORTED AND THAT THE ONGOING MAJOR PROGRAM ELEMENTS ARE CONSISTENTLY SUPPORTED AT THE LEVEL OF MOST COST EFFECTIVE OPERATION. THE RESULTING SDIO PROJECTIONS OF ESTIMATED FUNDING REQUIREMENTS FOR SPACE NUCLEAR POWER

RESEARCH AND DEVELOPMENT TOGETHER WITH DOE AND NASA ESTIMATES ARE FURNISHED ON FIGURE 5. I WOULD LIKE TO RE-EMPHASIZE THE VITAL ROLE PLAYED BY THE DEPARTMENT OF ENERGY AS PRINCIPAL AGENT IN PROVIDING ITS TECHNICAL AND MANAGERIAL SUPPORT AS WELL AS THE ASSISTANCE OF NATIONAL LABORATORY EXPERTS AND SPECIALIZED FACILITIES IN CONDUCTING THE RESEARCH AND DEVELOPMENT FOR THE SDIO SPACE NUCLEAR POWER SOURCES. NASA IS ALSO PROVIDING INCREASING LEVELS OF TECHNICAL SUPPORT PARTICULARLY IN ADVANCED SP-100 TECHNOLOGY AS THE PATHFINDER PROGRAM DEVELOPS NEEDS FOR SP-100 CLASS REACTORS FOR CIVIL FUTURE SPACE MISSIONS.

IN SUMMARY, I HAVE DESCRIBED THE NUCLEAR PROGRAM WHICH IS DEVELOPING THE POWER CAPABILITIES NEEDED TO SATISFY SDI REQUIREMENTS. AS THE PROGRAM ENTERS THE FIRST HARDWARE PHASES, REAL SCIENTIFIC AND ENGINEERING ACCOMPLISHMENTS HAVE BEEN ACHIEVED. WE ARE ENCOURAGED BY OUR PROGRESS AND LOOK FORWARD TO THE CHALLENGES OF THE INTENSE SCIENTIFIC AND ENGINEERING PROGRAMS WHICH LIE AHEAD. SUCCESSFUL PROSECUTION OF THESE EFFORTS WILL CONTRIBUTE NOT ONLY TO THE SUCCESS OF THE STRATEGIC DEFENSE INITIATIVE, BUT ALSO TO OUR COUNTRY'S EXPANDING INTERESTS IN SPACE WELL INTO THE NEXT CENTURY.

THIS COMPLETES MY FORMAL REMARKS. I WOULD LIKE TO THANK YOU AGAIN FOR THE OPPORTUNITY TO APPEAR BEFORE YOU. I WOULD BE HAPPY TO ANSWER ANY QUESTIONS THAT YOU MIGHT HAVE.

SPACE NUCLEAR REACTOR FUNDING PROJECTIONS

1. SP-100 GROUND ENGINEERING SYSTEM ($ IN MILLIONS)

	FY86	FY87	FY88	FY89
SDIO	15.9	36.5	30.0	55.0
DOE*	16.0	27.6	59.0	61.0
NASA	0	0	10.0	30.0
TOTAL	31.9	64.1	99.0	146.0

*INCLUDES SOME FLIGHT ENGINEERING SYSTEM FUNDING IN FY89

2. SP-100 ADVANCED CONVERSION TECHNOLOGIES ($ IN MILLIONS)

	FY86	FY87	FY88	FY89
SDIO	0.3	0.5	0.4	1.0
NASA	4.0	4.0	7.5	14.0
TOTAL	4.3	4.5	7.9	15.0

3. SP-100 FLIGHT OPTION ($ IN MILLIONS)

	FY86	FY87	FY88	FY89
SDIO	0	0	1.6	10.7

SPACE NUCLEAR REACTOR FUNDING PROJECTIONS (CONTINUED)

4. MULTIMEGAWATT SPACE REACTOR ($ IN MILLIONS)

	FY86	FY87	FY88	FY89
SDIO	8.0	5.9	5.0	10.0
DOE	0	1.7	4.0	13.0
TOTAL	8.0	7.6	9.0	23.0

5. THERMIONIC FUEL ELEMENT VERIFICATION ($ IN MILLIONS)

	FY86	FY87	FY88	FY89
SDIO	6.0	2.0	3.9	5.0
DOE	1.8	5.0	4.5	5.0
TOTAL	7.8	7.0	8.4	10.0

Mrs. **Lloyd**. Colonel, I apologize. We do have some votes again. I presume you have another half hour to stay with us.

Colonel **Hess**. Yes, ma'am.

Mrs. **Lloyd**. I'll be back as soon as I can get back. Thank you.

[Recess.]

Mr. **Morrison** [presiding]. We'd like to get the Subcommittee back underway. And Colonel Johnson, I think we're ready for your statement at this time. So, if you'd proceed, please.

Colonel **Johnson**. Yes, sir.

STATEMENT OF COL. JOSEPH R. JOHNSON, COMMANDER, U.S. AIR FORCE SPACE TECHNOLOGY CENTER, U.S. AIR FORCE SYSTEMS COMMAND, KIRTLAND AFB, NM

Colonel **Johnson**. I appreciate the opportunity to testify before you on the issue of space nuclear power systems. In the interests of time, I think I can shorten my statement to a summary, really, because everything that has already been said is something that I could echo.

But your letter inviting Air Force testimony asked two specific questions, and I'll try and succinctly summarize my testimony, and answer them in sequence.

The first dealt with the projected need for space reactors. Let me simply assert my belief that future U.S. military spacecraft will require nuclear reactor power sources in addition to the programs that are being considered under the Strategic Defense Initiative.

I cannot say which spacecraft will be the first to use nuclear power or when. However, for a number of reasons I contend that our eventual use of space reactors is inevitable.

Recent studies conducted by the Air Force Space Technology Center indicate that military space power requirements could grow by an order of magnitude in the next 20 years. And, as spacecraft power levels increase, nuclear reactor power systems should become more attractive than solar power systems because of their advantageous size and weight characteristics.

For example, a 40-kilowatt-electric SP100-type power system is projected to be approximately two-thirds as heavy and less than one-tenth the size of an equivalently-hardened solar power system. And at very high continuous power levels, nuclear reactors become the only practical alternative.

As Colonel Hess has already indicated, it is important that military spacecraft be capable of surviving a variety of hostile threats. And space reactor power systems offer the potential for significantly increased survivability. Space reactors are much more compact than solar arrays, and reactors are constructed of materials that are inherently harder.

And as Soviet anti-satellite weapons continue to increase in capability, we must find ways to protect our space assets. And I submit that the need for survivable spacecraft will eventually compel us to employ reactors.

When addressing the Air Force need for space reactors, one might also consider Soviet activities in this arena, an area which Mr. Morrison has already alluded to. Since the U.S. launched the world's first space reactor in 1965, the Soviet Union has launched and operated some 30 nuclear power reactors.

I suspect they have such an aggressive national space reactor program because they, too, recognize the long-term importance of this technology. Accordingly, they are building an enviable technical data base and gaining valuable operational experience.

To repeat, primarily because of increasing power demands and survivability considerations, I believe that the Air Force will need space nuclear reactors in the future.

The second question that you asked concerns the level of technology development required to permit the Air Force to apply space reactor power systems to our missions. Before the Air Force can commit to the routine operational application of space nuclear reactors, I think three things must happen.

First of all, the basic technology must be developed and design techniques must be validated;

Second, a demonstration reactor power system must be formally flight qualified; and

Third, the reactor power systems as a whole, I believe, must be first demonstrated in space.

Active programs are now in place to address each of these technology readiness issues, and we've discussed them this afternoon. The Ground Engineering System is now underway with the goal of developing SP-100 technology and carefully validating the design methods required to engineer flight-ready nuclear power systems.

The projected output of this effort is indeed a fully-developed data base that defines the necessary nuclear materials and energy conversion technology.

As an executing agent for SDIO, the Air Force is laying the groundwork for flight qualification of the SP-100. The Air Force team conducting this effort is now in the process of tailoring the military standards we currently use to flight-qualified conventional spacecraft. The objective is to produce a revised set of technical procedures that can be properly applied to flight qualify the unique and complex features of space nuclear reactors to ensure safe and reliable operation.

And then the final step in the technology-readiness equation is the system-level demonstration that can be conducted as a flight experiment or, possibly, as part of an actual operational mission.

The eventual goal of our work for SDIO is to demonstrate on orbit the successful operation of a space nuclear reactor system, powering an experimental payload. We think it essential that the Air Force play a central role in this process. As an active participant in the program, the Air Force will best be able to assess any unresolved technology readiness issues that may arise.

Moreover, highly-involved Air Force participation in the launch and operation of the SP-100 will build within the Air Force a technically trained and experienced infrastructure that is fully prepared to field the reactors the Air Force will need in the future.

In summary, in response to your two questions, the Air Force, I believe, will inevitably require space nuclear power systems, and the necessary level of technology development can best be achieved by the successful flight demonstration of an operating reactor.

Making these power sources available, I believe, will be a technical and political and economic challenge. But for reasons of survivability and power demand, I believe we must and I believe we can meet the challenge.

More importantly, I believe that, once the first mission is successfully completed and we consider nuclear power as, quote, "on the shelf," unquote, the number of users for space reactor systems will rapidly expand.

Thank you for the opportunity to share with you the story of Air Force participation in this important technology.

[The prepared statement of Colonel Johnson follows:]

DEPARTMENT OF THE AIR FORCE

HOUSE OF REPRESENTATIVES

SUBJECT: Space Nuclear Reactor Power Systems

STATEMENT OF: Colonel Joseph R. Johnson
Commander, Air Force Space Technology Center
Air Force Systems Command
Kirtland AFB NM

Date: 16 March 1988

NOT FOR PUBLICATION UNTIL RELEASED
BY THE COMMITTEE ON SCIENCE, SPACE,
AND TECHNOLOGY, HOUSE OF REPRESENTATIVES

MADAM CHAIR AND MEMBERS OF THE COMMITTEE

Thank you for the opportunity to testify before your subcommittee on the issue of space nuclear reactor power systems. This topic is important to those of us in the Air Force who are responsible for ensuring that US military spacecraft maintain the technological advantage that is the cornerstone of our national security strategy. The letter inviting Air Force testimony asked two specific questions: (1) What is the Air Force's projected requirement for compact nuclear reactors like the SP-100? and, (2) What level of technology development is needed to permit the use of nuclear reactors for Air Force space missions? I've structured my remarks to address these questions in sequence.

AIR FORCE REQUIREMENT FOR SPACE NUCLEAR REACTOR POWER SYSTEMS

To the question about the projected need for space reactors, I assert my belief that future US military spacecraft will require nuclear reactor power sources. I cannot say which spacecraft will be the first to use nuclear power or when; however, I contend that our eventual use of space reactors is inevitable. There are a number of reasons why I believe that nuclear reactor power systems will be a part of our future military space program.

The United States is committed to an expanded role in space. Without improved space assets, the national security will be at risk. We cannot afford to shy away from a wide-ranging, steady technology program designed to enhance our space capability. As our role in space expands, electric power levels of space platforms will increase. Recent studies conducted by the Air Force Space

Technology Center indicate that military space power requirements could grow by an order of magnitude in the next 20 years.

As spacecraft power levels increase, nuclear reactor power systems should become more attractive than solar power systems because of their advantageous size and weight characteristics. For example, a 40 kilowatt-electric SP-100 type power system is projected to be approximately two-thirds as heavy and less than one-tenth the size of an equivalently hardened solar power system. At very high continuous power levels, nuclear reactors become the only practical alternative.

Obviously, it is important that military spacecraft be capable of surviving a variety of hostile threats. Space reactor power systems offer the potential for significantly increased survivability. Space reactors are much more compact than solar arrays, and reactors are constructed of materials that are inherently harder. As Soviet anti-satellite weapons continue to increase in capability, we must find ways to protect our space assets. Innovative survivability techniques that involve maneuver and tracking denial will be enabled by the high power densities that reactors provide. I submit that the need for survivable spacecraft will eventually compel us to employ reactors.

Another major factor that is driving us towards the widespread use of space reactors is economics. Nuclear reactor power systems, when combined with electric propulsion, can significantly reduce the cost to get spacecraft into high-energy operational orbits. We cannot afford to continue the current rising trends in cost per pound on orbit. Innovative orbit transfer systems, like nuclear electric propulsion, will become essential to an expanded and affordable Air Force role in space.

When addressing the US Air Force need for space reactors, one might also consider Soviet activities in this arena. The US launched the world's first space reactor, SNAP-10A, back in 1965. Since that time, while we have yet to field our second space reactor, the Soviet Union has launched and operated some 30 nuclear power reactors. They have placed reactor power subsystems on satellites which could employ solar panels to perform the same mission. It's important to ask the question, "Why have the Soviets gone to the trouble to develop and use nuclear reactors when solar could have done the job?" I suspect they have such an aggressive national space reactor program because they, too, recognize the long-term importance of this technology. The Soviets also apparently believe that, for some applications, space reactors might be their only viable alternative. Accordingly, they are building an enviable technical data base and gaining valuable operational experience.

To reiterate, primarily because of increasing power demands and survivability considerations, I believe that the Air Force will need space nuclear reactors in the future.

REQUIRED TECHNOLOGY DEVELOPMENT LEVEL

The second question you've asked concerns the level of technology development required to permit the Air Force to apply space reactor power systems to our missions. Although space reactor systems and components are highly complex, we can determine whether the level of technology development is adequate to allow its use on Air Force systems.

Before the Air Force can commit to the routine operational application of space nuclear reactors, three things must happen: (1) The basic technology must be developed and design techniques must be validated, (2) A demonstration reactor power system must be formally flight qualified, and (3) The reactor power system as a whole must be demonstrated in space. Active programs are now in place to address each of these technology readiness issues.

By law, the Department of Energy (DOE) is responsible for developing military reactor technology. DOE's SP-100 Program has formulated the Ground Engineering System (GES) to do this job with additional funding support from SDIO and NASA. The Ground Engineering System is now underway with the goal of developing SP-100 technology and validating the design methods required to engineer flight-ready nuclear power systems. The projected output of this effort is a well understood data base that contains the necessary nuclear, materials, and energy conversion technology, validated component and subsystem life models, and accredited design tools.

As executing agent for an SDIO task, Space Reactor Flight System, the Air Force is laying the groundwork for flight qualification of the SP-100. The Air Force team conducting this effort is now in the process of tailoring the Military Standards we currently use to flight qualify conventional spacecraft. The objective is to produce a revised set of technical procedures that can be properly applied to flight qualify the unique and complex features of space nuclear reactors. To save time and money on the national space reactor program, we have begun working with DOE to ensure that the component and subsystem testing conducted in their Ground Engineering System project dovetails smoothly and intelligently with that required for flight qualification.

The final step in the technology readiness equation is the system level demonstration that can be conducted as a flight experiment or, possibly, as part of an actual operational mission. The eventual goal of our work for SDIO is to demonstrate on orbit the successful operation of a space nuclear reactor system powering an experimental payload. The Air Force team managing this task will be responsible for designing the experimental payload, defining mission parameters, managing the flight qualification process, integrating the flight subsystems, and launching and operating the reactor powered spacecraft.

We think it essential that the Air Force play a central role in this process. As an active participant in the program, the Air Force will best be able to assess any unresolved technology readiness issues that may arise. Moreover, highly involved Air Force participation in the launch of the SP-100 will build within the Air Force a technically trained and experienced infrastructure that is fully prepared to field the space reactors the Air Force will need in the future.

SUMMARY

Thus, in response to your two questions, the Air Force will inevitably require space nuclear reactor power systems, and the necessary level of technology development can best be achieved by the successful flight demonstration of an operating reactor. Making these reactor power sources available will be a technical, political, and economic challenge. Still, for reasons of survivability and power demand, I believe we must and can meet this challenge. More importantly, I believe that once the first mission is successfully completed and nuclear power is "on the shelf," the number of users for space reactor systems will rapidly expand.

The attached exhibits provide more detailed information on points raised in the oral presentation.

Exhibit 1 is an unclassified review of Air Force and SDI power requirements. This information was gathered as part of a study performed by the Air Force Space Technology Center. Specific power requirements for a given system are not shown in order to keep the chart unclassified. However, the trend towards increasing power demands for future space systems is clear.

Exhibit 2 contains two graphs which demonstrate the mass savings that space nuclear power systems can provide and the significant reduction in area that the nuclear systems achieve. Graph 1 is a plot of electric power level versus mass for both advanced and near term space reactor concepts. Near term concepts are those which can be flight ready in the 1992-95 time frame, and advanced concepts are those that can be ready in the 1995-98 time frame. Graph 2 illustrates the power system area for a given electric power output. The two solar power systems shown are the Survivable Concentrating Photovoltaic Array (SCOPA) and the same survivable solar concept using an improved efficiency cell referred to as Multiband Gap. The nuclear systems plotted bracket the range of potential reactor power system areas. These systems are referred to by the type of energy conversion technique they use because this determines the heat rejection temperature and radiator area. The Brayton Cycle has a high energy conversion efficiency but a fairly low temperature, and therefore large radiator. Thermionic systems usually have a lower conversion efficiency but a much higher heat rejection temperature and a correspondingly small radiator. An SP-100 technology system would be plotted somewhere between the Brayton and

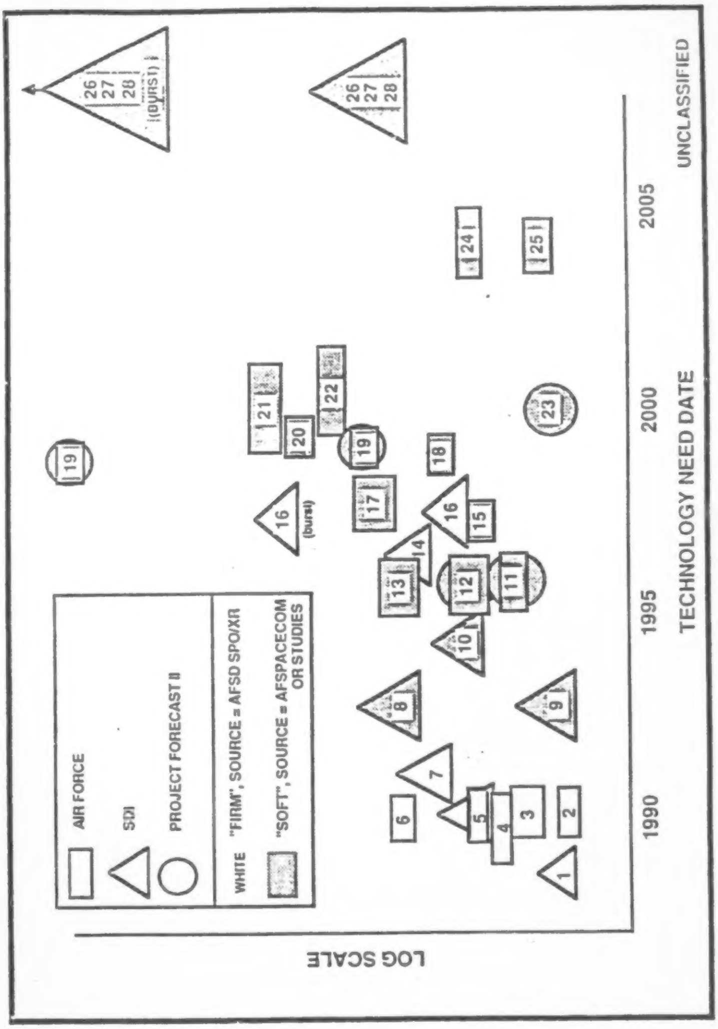
Thermionic systems. These charts are based on several assumptions which can change as technologies become more mature; however, the trends illustrated in the two graphs will remain the same.

Exhibit 3 is a table from the open literature which lists the known Soviet launches of space nuclear reactor systems.

Exhibit 1

UNCLASSIFIED

(U) SPECTRUM OF POWER REQUIREMENTS

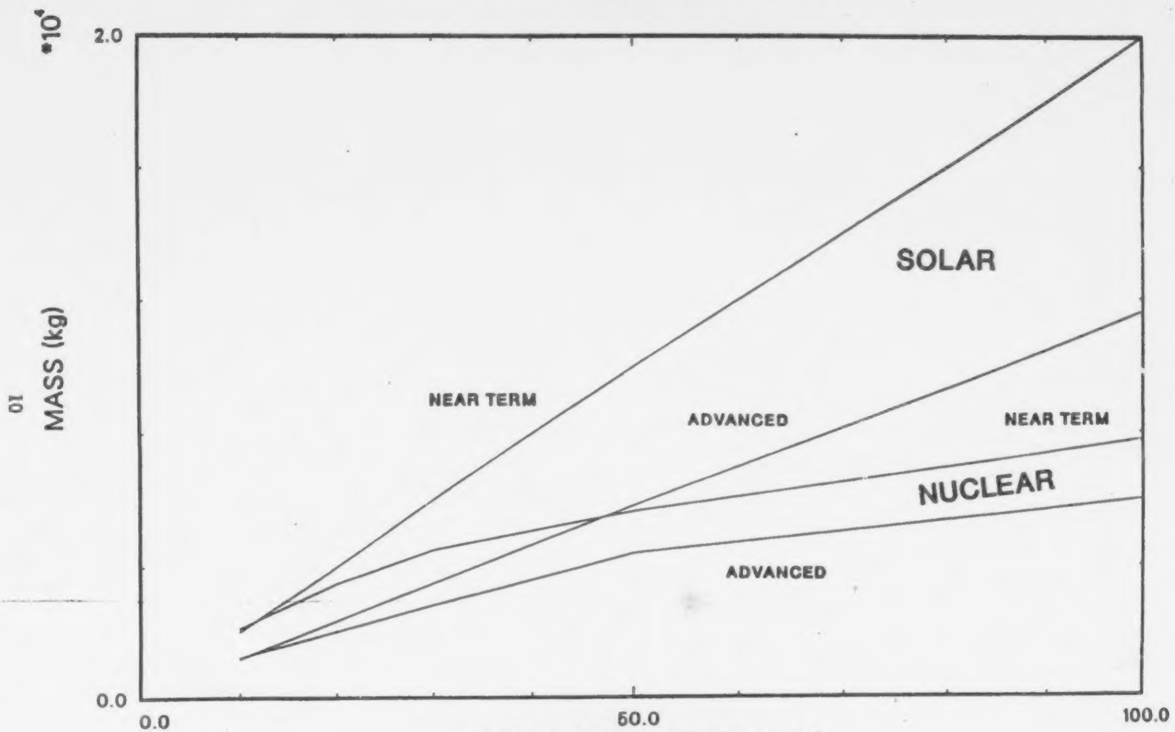


UNCLASSIFIED

Exhibit 2
Graph 1

UNCLASSIFIED

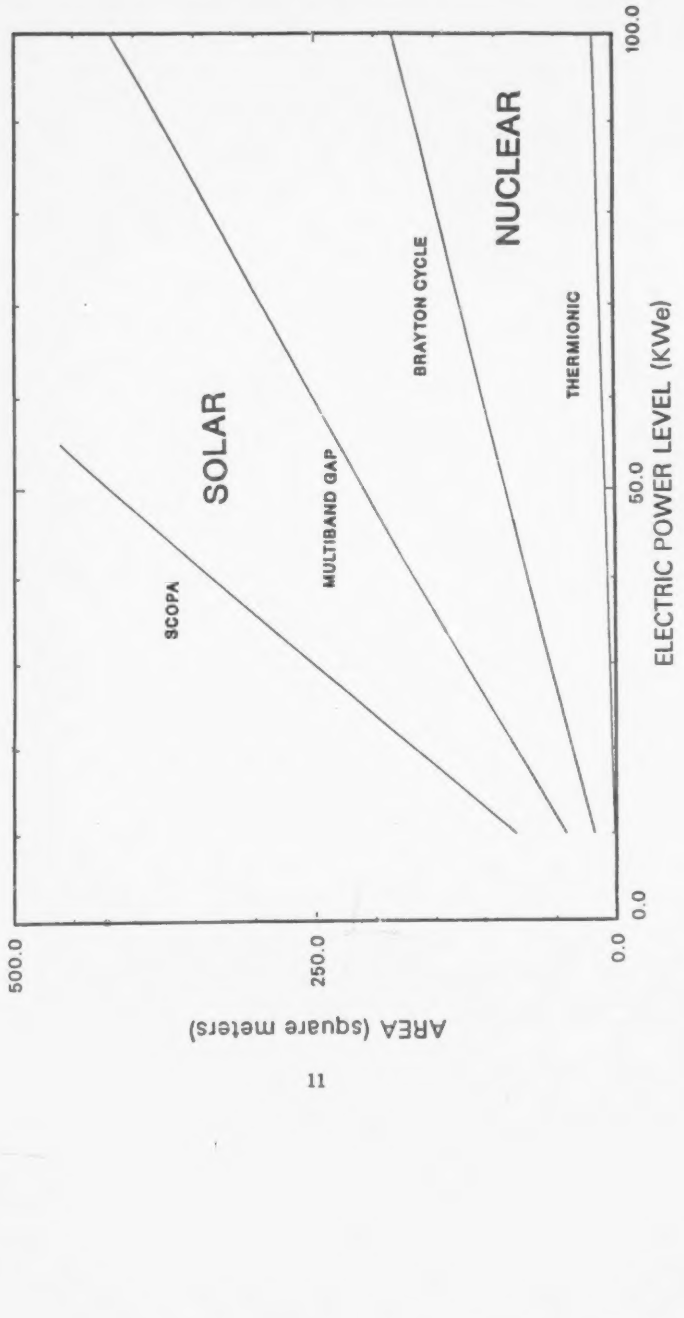
POWER SYSTEM MASS vs POWER LEVEL



UNCLASSIFIED

Exhibit 2
Graph 2

UNCLASSIFIED



POWER SYSTEM AREA vs POWER LEVEL

UNCLASSIFIED

Exhibit 3

Soviet Nuclear Reactor Powered Satellites

Date	Satellite	Lifetime (Days)	Comments
Dec 67	Cosmos-198	2	Test?
Mar 68	Cosmos-209	6	Test?
Jan 69	-	-	Launch Failure?
Oct 70	Cosmos-367	1	Test?
Apr 71	Cosmos-401	8	
Dec 71	Cosmos-469	10	
Aug 72	Cosmos-516	31	
Apr 73	-	-	Launch Failure
Dec 73	Cosmos-626	44	
May 74	Cosmos-651	71	
May 74	Cosmos-654	74	
Feb 75	Cosmos-723	44	
Apr 75	Cosmos-724	66	
Dec 75	Cosmos-785	1	Failure
Dec 75	-	-	Apparently a second launch was planned but cancelled because of the failure of the first payload?
Oct 76	Cosmos-860	24	
Oct 76	Cosmos-861	60	
Sep 77	Cosmos-952	22	
Sep 77	Cosmos-954	-	Re-entered over Canada
Apr 80	Cosmos-1176	135	Test of "Fixes" for Cosmos-954
May 81	Cosmos-1249	106	
Apr 81	Cosmos-1266	8	Failure?
Aug 81	Cosmos-1299	13	Failure?
May 82	Cosmos-1365	136	
Jun 82	Cosmos-1372	71	
Aug 82	Cosmos-1402	120	Re-entered over Indian Ocean and South Atlantic
Oct 82	Cosmos-1412	39	Failure?
Jun 84	Cosmos-1579	90	
Oct 84	Cosmos-1607	93	
Aug 85	Cosmos-1670	84	
Aug 85	Cosmos-1677	60	
Mar 86	Cosmos-1736	92	
Aug 86	Cosmos-1771	56	

Biography

United States Air Force

AIR FORCE SPACE TECHNOLOGY CENTER, KIRTLAND AIR FORCE BASE, NEW MEXICO 87117

COLONEL JOSEPH RANDALL JOHNSON

Colonel J. R. Johnson is Commander of the Air Force Space Technology Center (AFSTC) at Kirtland Air Force Base, New Mexico.

The primary AFSTC mission is to provide advanced technology for future military space systems. Three Air Force laboratories report to the center: the Air Force Astronautics Laboratory at Edwards Air Force Base, California; the Air Force Geophysics Laboratory at Hanscom Air Force Base, Massachusetts; and the Air Force Weapons Laboratory at Kirtland Air Force Base, New Mexico. The center has 2,300 people and an annual budget exceeding $750 million.

Col Johnson was born May 16, 1940, in Pittsburgh, Pennsylvania. His undergraduate studies at Illinois Institute of Technology led to a bachelor of science degree in mechanical engineering in 1963 and his commissioning through the Air Force Reserve Officers Training Corps' Distinguished Graduate Program. He received a master's degree in mechanical engineering from Stanford University in 1964. Colonel Johnson is a distinguished graduate of the residence program of the Air Command and Staff College in 1975 and the residence program of the Industrial College of the Armed Forces in 1982.

Following graduation from Stanford University, Colonel Johnson was assigned as project engineer in the Spacecraft Recovery Office of Space and Missile Systems Organization in Los Angeles, California, where he managed modification and test of unique JC-130 aircraft recovery equipment and recovery subsystem development and technical support for two space programs. In 1968 he was assigned as the chief of the Hardware Support Branch, Air Force Satellite Control Facility in Sunnyvale, California, managing 24-hour-a-day support and technical problem resolution for multiple satellite operations. Also, he directed engineering changes to world-wide remote tracking stations.

Moving to the Air Force Avionics Laboratory at Wright-Patterson Air Force Base, Ohio, in 1972, he served as a staff engineer, working directly for the commander on special technical management projects and initiating action to satisfy all requests for laboratory assistance.

Following attendance at Air Command and Staff College, Colonel Johnson returned to Wright-Patterson in 1975 as a program manager for the Remotely Piloted Vehicle (RPV) System Program Office, Aeronautical Systems Division. There he managed six separate tasks of the RPV Advanced Launch and Recovery development program and conceptual phase activities for an advanced RPV program. In 1978 he attended the Program Management Course at the Defense Systems Management College, Fort Belvoir, Virginia.

Later that year, Colonel Johnson was assigned to Headquarters, Air Force Systems Command at Andrews Air Force Base, Maryland, where he was first an acquisition management adviser with the Program Management Assistance Group, providing consultation services to program managers, system program directors, and division and center commanders throughout the command. He then became the assistant for Senior Officer Management, responsible to the commander for personnel actions of general officers and colonels assigned to the command. After attending the Industrial College of the Armed Forces, he moved to the Pentagon in 1982 to become chief of the Strategic Command, Control and Communications Division for the Deputy Chief of Staff, Research, Development and Acquisition.

Colonel Johnson assumed command of the Air Force Geophysics Laboratory in July 1985. He left in August 1987 to command the Air Force Space Technology Center.

Colonel Johnson's awards and decorations include the Legion of Merit, the Meritorious Service Medal and the Air Force Commendation Medal with three oak leaf clusters. He was promoted to Colonel on October 1, 1982, with date of rank of February 16, 1982.

Colonel Johnson is married to the former Judith L. Anderson of Hinsdale, Illinois. They have two sons, David and Mark.

-AFSTC-

October 1987

PANEL 1 DISCUSSION

Mrs. Lloyd [presiding]. Thank you for your testimony. Again, my apologies for keeping you waiting. We had abandon the hearing to vote.

Colonel Hess, as I explained and as you heard from the NASA witness, it is my view that the use of nuclear reactors in space is going to be highly dependent on our flight demonstration of the power systems. And I think this will have to be done before we have actual mission applications.

Do you think that the mission planners will ever incorporate nuclear power into their spacecraft unless we do have a successful flight demonstration?

Colonel Hess. In answer to that question, I'd like to say that I believe that before that demonstration the technical feasibility questions can be answered satisfactorily. But, as I indicated in my remarks, these same respective space program managers that are currently in Space Division primarily are going to have to be shown that the process can be addressed and that you can get through that process, through the bureaucracy, through the hearings, through the court challenges that one might reasonably anticipate, in an expeditious manner and at a reasonable cost.

And by flying a demonstration mission and going through that process and setting a precedent—not only a technical precedent, but a legal precedent—I believe that we can convince them that this technology is ready to fly.

Obviously, the short answer to your question is that that demonstration is clearly a cost of doing business, a prerequisite to acceptance by the program managers of this technology.

Mrs. Lloyd. Well, the flight demonstration would satisfy the requirements that you've just mentioned.

Colonel Hess. Yes, ma'am.

Mrs. Lloyd. What do you think will happen to the SP-100 program if NASA doesn't get the funding for the Pathfinder Program in the 1989 budget?

Colonel Hess. We're always revisiting the issue of matching program scope to available funding. We had to do that this year. Our funding from SDIO was significantly reduced. I believe that we can adapt the program requirements.

There's the always the issue of stretch-out and additional costs associated with that. I believe that we can have a meaningful program. Of course, I believe it's critical that NASA get that funding so that they can remain a full partner and can influence the evolution of this system to meet civil requirements.

Mrs. Lloyd. Thank you very much.

Colonel Johnson, it is my understanding that the SDIO is exploring some potential international cooperative options for a flight demonstration of a space nuclear reactor. And you mentioned the Soviets' use of nuclear reactors in space, as well. Do you really believe there is a basis for seeking the cooperative programs to develop and test our nuclear reactor systems in space on a cooperative basis?

Colonel Johnson. I'm not familiar with those explorations. I think that we could look for international cooperation in flying experiments on board a demonstration. As far as developing the nuclear power system itself, I'm not familiar with any overtures that might have been made.

Mrs. LLOYD. Well, what kind of mission are you exploring as a cooperative venture?

Colonel JOHNSON. As a community, we have just begun to look at the various things. As Colonel Hess presented, we are principally looking at electric propulsion as one of the experiments that could be used. The Air Force has been looking at a number of other activities where we might fly technology demonstrations on board something like that.

Space-based radar would be nice to test in that environment. Transmit-receive modules for various types of activities. It might be nice to fly a cryo-cooler if it's ready at that point in time. Those are the kinds of things that people have begun to look at.

And we're just now, as a community, beginning to put together a structure to define that. So, we're at the preliminary stages now. But I'm not familiar with any specific international activity.

Mrs. LLOYD. Very good. Colonel Hess, would you like to address this?

Colonel HESS. Yes, ma'am. The areas that we are seeking to explore in that area or have been suggested, as I indicated, by Senator Bennett Johnston was that we might mutually find it advantageous to develop standards for safety that would be acceptable in the U.N. and to the community of nations to assure the people outside the Soviet Union and outside the United States that these two countries that are prospective users of nuclear power have given adequate consideration to the issue of nuclear safety.

The Soviets would have every reason, I believe, to want to cooperate in that area. They suffered politically somewhat of a black eye in the area of relationships when they had Cosmos land in Canada. And cooperative arrangements with the United States would be an area of cooperation, I think, that they might be willing to pursue.

Mrs. LLOYD. Thank you very much. Mr. Morrison?

Mr. MORRISON. Gentlemen, obviously, the Soviets have a lot of experience in launching these things into space. But do we know much about what the capabilities of those reactors are?

Colonel HESS. We have every indication that they are thermoelectric systems. They are not particularly advanced.

Soviet technology is very utility-oriented. They saw a need. They developed a basic system. And they were prepared to fly it.

In retrospect, they did not give adequate consideration to safety, in our opinion, by our standards. But it does represent an experience base that they're gaining. And clearly, they are engineering refinements into their system, and gaining valuable experience, just as they are in space stations on operations in space.

A description of what we have learned about their capabilities is outside the scope of what we could discuss here. But those briefings are available for the Committee in the appropriate settings.

Mr. MORRISON. Yes, we would understand. I guess I'm sort of exploring what we might gain, if there are any plans to work with them. Certainly they've fired a lot of things into the air. I'm not sure what they have put up, whether their experience really relates to the direction we're going at all, which seems to be centered around safety and reliability once we're up there.

Colonel **Hess**. The area that I spoke of earlier, their mutual interest in the safety issue and assuring the world community that both of us are acting responsibly, I think, would be the area most likely for joint participation.

Mr. **Morrison**. I would think that certainly would be to their advantage. Perhaps also to ours.

No other questions, Madam Chairman, except just to say that I think the value of a willingness to participate in the Pathfinder Program is certainly underscored by both of their testimonies.

Mrs. **Lloyd**. Thank you very much. Mr. Fawell?

Mr. **Fawell**. No questions, Madam Chairman.

Mrs. **Lloyd**. Thank you very much. Thank you, gentlemen, for being with us today. We look forward to your further participation in the hearings of this Committee.

[Questions and answers for the record for Colonel Hess follow:]

INSERT FOR THE RECORD

☐	HOUSE SENATE	APPROPRIATIONS COMMITTEE	☐	HOUSE SENATE	ARMED SERVICES COMMITTEE	☒	HOUSE SENATE	Science, Space and Technology

HEARING DATE	TRANSCRIPT PAGE NO.	LINE NO.	INSERT NO.	
16 Mar 88				Q 1

QUESTION: Is the SDIO studying the feasibility of exploring potential international cooperative options for a flight demonstration of a space nuclear reactor? If so, please describe the potential options and your efforts thus far. Also please indicate when you might inform the Committee as to whether or not such options are feasible and when and under what circumstances such cooperation might be planned?

ANSWER: SDIO if not currently studying the feasibility of exploring potential international cooperative options for a flight demonstration of a space nuclear reactor. However, we are initiating inquiries on the international exchange of information relative to launch and operational safety as well as permanent disposal of spent space nuclear power reactors. These involve DoD, State Department, DOE and NASA collaboration. If such an exchange could be accomplished, and it fosters belief that international agreements covering these matters would be in the best interests of the US, further discussions to that end would be conducted. An option providing for international cooperation in a flight demonstration of a space nuclear reactor could be considered for inclusion on the agenda of such discussions. The Committee will be kept fully informed of the status of these studies and discussions.

INSERT FOR THE RECORD

	HOUSE SENATE	APPROPRIATIONS COMMITTEE		HOUSE SENATE	ARMED SERVICES COMMITTEE	X 	HOUSE SENATE	OTHER Science, Space and Technology
HEARING DATE 16 Mar 88		TRANSCRIPT PAGE NO.		LINE NO.		INSERT NO.		Q 2

QUESTION: You state that, "If a decision is made to proceed with a phased strategic defense deployment, the required development schedules for the necessary power systems become very tight." (P.8) How tight would this schedule be? Specifically, what advances will have to be made to have a demonstration energy source for space-based systems? How do the development of these power sources differ if a SDI Phase I System is planned for deployment in the mid-1990's rather than if a long-term, more comprehensive strategic defense is pursued?

ANSWER: A schedule for the power systems to support a phased strategic defense deployment would be stringent. An initial phase would use survivable solar powered systems. Survivable solar power development programs are funded by SDIO to augment the Air Force Survivable Concentrator Photovoltaic Array program (SCOPA) and to design and test a much harder system called the Survivable Power Module (SUPER). These provide technological development of materials and structures for a survivable and reliable solar array to be flight demonstrated in FY1992 and thus could support the Phase I technology readiness decisions. Advances are required in solar cell efficiency, array packaging and manufacturing methods for cost-effective production of the quantity of solar arrays required. SP-100 would be needed to support follow-on phases that require increased power levels, specific power and hardness. SP-100 ground engineering testing should be completed by 1993/1994 and, to gain acceptance, should be moving into the flight testing.

A demonstrated energy source for space based systems requires flight testing of hardware modules. This is planned for the SUPER program in 1992; a 5-10 kW module will be flight tested. For SP-100, flight testing is planned for 1996. This will be a 30-100 kW power system. The testing will not only demonstrate the technical readiness of SP-100, but it will also demonstrate that the safety and other issues associated with launch and space operations of nuclear power systems can be successfully accomplished.

Our long-term, robust strategic defense research plans include development of a broad range of technologies and systems including nuclear reactors to provide the extremely high power level and total energy demands required by sensors and weapon systems in a comprehensive SDI architecture. Solar and nuclear power systems are complimentary. Both would be needed to meet different SDI platform requirements. These power sources will require an intense research and development program to advance the state of the art in realizing rugged, reliable and affordable mass-effective systems. Continuity of funding is essential to ensure that milestones are achieved.

INSERT FOR THE RECORD

☐	HOUSE SENATE	APPROPRIATIONS COMMITTEE	☐	HOUSE SENATE	ARMED SERVICES COMMITTEE	☒	HOUSE SENATE	OTHER Science, Space and Technology

HEARING DATE 16 Mar 88	TRANSCRIPT PAGE NO.	LINE NO.	INSERT NO.	Q 3

QUESTION: You state that "The SP-100 will supply baseload power for seven to ten years of unattended operation." (P.4) Can you tell me what power source could back up the energy supplied by this system in case of failure? Will there be a capacity for attending to problems with a deployed system once it is in space? After a 7-10 year cycle, what is the probability that the inactive satellite would remain in orbit? Would the satellite be moved to a different orbit?

ANSWER: Because of the extremely high power and total energy requirements of the SP-100 applications there is no practical backup for this nuclear reactor power supply. The SP-100 is being designed to demanding survivability and reliability specifications which will ensure mission performance in its operational deployment.

In addition to the usual reactor control and safety systems, sufficient battery energy storage will be kept available to provide for safe and permanent shutdown of the reactor at the end of life or in the improbable event of accidental or enemy induced damage to the reactor.

At the end of reactor life, the SP-100 will remain in an orbit lasting thousands of years, the orbits currently planned for use by SDIO. Orbit lifetimes of at least 300 years provide for decay of the fission products to safe radiological levels. If shorter life orbits were used, an on-board boost system would be included for end-of-life boost. As additional assurance, safety measure investigations are underway for deep space permanent disposal. These measures are to assure that no hazardous substances will ever re-enter the earth's atmosphere as a result of SP-100 operations.

PANEL 2: U.S. DEPARTMENT OF ENERGY LABORATORIES

Mrs. **LLOYD.** Our next three witnesses will appear before us as a panel. Mr. A. William Snyder, the Director of Exploratory Nuclear Power at Sandia National Laboratories; Dr. Charles Till, the Associate Laboratory Director for Engineering Research and Development at the Argonne National Laboratory in Idaho; and Dr. W. Howard Arnold, the Vice President of Hanford Westinghouse, who is accompanied by Dr. Michael Korenko.

Gentlemen, I do welcome you. Your written statements will be made a part of the record. If you would, please, summarize them as you present your testimony. And I believe Mr. Snyder will begin.

STATEMENT OF A. WILLIAM SNYDER, DIRECTOR, EXPLORATORY NUCLEAR POWER DEVELOPMENT, SANDIA NATIONAL LABORATORIES, ALBUQUERQUE, NM

Mr. **SNYDER.** Madam Chairman, I am Bill Snyder, Director of Exploratory——

Mrs. **LLOYD.** Excuse me, Mr. Snyder. Your mike is not on.

Mr. **SNYDER.** Thank you.

Madam Chairman and Members of the Subcommittee, I am Bill Snyder, Director of Exploratory Nuclear Power Development at Sandia National Laboratories. My responsibilities at Sandia include space and terrestrial nuclear power, but I'm going to limit myself to Sandia's views on commercial nuclear-electric power and the Federal research and development program in support of it.

Our desire to present our views stems from a concern that we have as a laboratory, that the future viability of nuclear fission energy as an option among the primary energy sources for the generation of electrical energy in the U.S. is tenuous and that insufficient steps are being taken to preserve and strengthen the option, the nuclear option, in the national interest.

Further, our views stem from a conviction that we can and should reestablish the U.S.'s preeminence in nuclear-electric power and should support it with a modified agenda for civilian nuclear energy research and development. We observe that the U.S. has been preeminent in developing the technology of the reactor part—and I emphasize the reactor part—of nuclear-electric power plants. We believe that correspondingly the U.S. should become preeminent in the development of the technology of the non-reactor balance of nuclear-electric power plants in order to support the design and construction of plants that will be an optimum national energy option and an international commercial asset.

I will propose and provide arguments to justify a somewhat modified agenda of research and development with the vision of recapturing for the future the intrinsic benefits of nuclear fission energy. Much of what I will propose is already contained in the Department of Energy's Fiscal Year 1989 nuclear fission energy research and development budget request. That which is not in the budget derives from Sandia's views on what should be the vision and the goals for nuclear energy, and what are the current conditions of the nuclear-electric power in the U.S.

In a period—and I want to look back and say, take stock of where we now are in commercial nuclear-electric power in this country—in a period of 30 years, we have developed an industry in the U.S. nuclear energy to generate 18 percent of our energy demand. But let's look at it another way. What we are supplying at the moment is 6 percent of our primary energy consumption with nuclear fission energy. That looks like a substantial contribution until you compare it, in fact, with what has been done in other industrialized nations of the world.

Our 6 percent has been eclipsed by most advanced industrialized nations and regions in the world outside of centrally-planned economy areas.

The relative contribution of nuclear fission energy to the U.S. primary energy supply has really not fulfilled the expectations of the technical, the industrial, and the political leaders who were the pioneers and the architects of our nation's nuclear energy program. Had those expectations been realized, today we would be looking at something about three-fold the amount that we are now producing as a percentage of our primary energy consumption. That would, in fact, have the consequences of offsetting some of our current dependence on imported oil.

Now why those original objectives and the contributions of nuclear energy to a primary energy supply have not been achieved is debated, hotly debated, and you know most of the arguments as well as I do, and I will not recite them here. But I find the usefulness of most of those arguments that are waged over why we haven't come as far as we should in nuclear energy are really of little utility in trying to define what we should do in the future.

I make that observation because those arguments failed—their utility fails to distinguish between what are the symptoms we have of the problem today and what are the underlying causes of the current conditions of commercial nuclear power. I think we need to understand first and foremost what technical features of current plants and what legacies of institutional features are the root cause of the current conditions and are stalemating achieving the intrinsic benefits from nuclear energy and what is certainly to impede our ability to advance into a second nuclear-electric power area independent of what the primary coolant technology is.

I want to observe and make very emphatic that the future of nuclear-electric power in the U.S. should optimally consist of two parts. The first part is going to be the legacy of 120 plants, when all the plants that are now, in fact, operating and under construction are then operating. That's the most crucial part of the future.

The second part of the future is the plants yet to be built with the same or another primary coolant technology. I would observe that a necessary condition of a viable future is finding the means institutionally and technically to improve the legacy of the 120 plants of the first nuclear era.

Let me look first now at the matter of how we improve the legacy, the essential and first part of the future. In my opinion, it is most unlikely that the current causal conditions impacting the viability of commercial nuclear-electric power in the U.S. can be resolved and solely by the legislation on regulatory reform. Certainly regulatory reform needs to be cleansed of a lot of features that appear to have the effect of making a virtue of indecision. We need to correct that, but that, I think, is not a sufficient condition to move ahead in the future.

What is really important is a fundamental goal for the first 120 plants to correct the causal conditions that have contributed to the symptoms of the current condition. You know those symptoms as well as I do: poor average availability of current plants, a lingering anxiety over the safety of plants, and complex technical regulatory issues.

In searching for about a year for what is, in fact, the underlying causal factor that leads to the present condition, I conclude that the common cause for practically all of the symptoms is relatively poor plant reliability, manifest in low availability, manifest in a high frequency of unanticipated automatic trips of the plants or outages.

Now the utility industry has responded in a very commendable way by trying to achieve excellence in operations and maintenance. That's a necessary thing to do, but it is not sufficient.

It is our view that the fundamental goal of the Federal effort on civilian nuclear energy should be to focus greater resources and commitment on attaining approved balance-of-plant and other non-nuclear component designs in concert with the nuclear industry—the nuclear steam supply system vendors, the balance-of-plant component suppliers—in order to attain greater reliability of the first generation of nuclear-electric plants.

The nuclear technology of the fuel, the reactor core, the design of that core, the shielding, the instrumentation of the core is absolutely first rate, and it is a preeminent contribution of this country to nuclear-electric power worldwide.

In contrast, the non-nuclear technology supporting the attainment of quality and reliability requisite to optimum economic viability and enhanced safety, both real and perceived, has been poorly supported by Government. I would observe parenthetically that it's been about 20 years since there has been a significant amount of research put in some of the most vital elements of both nuclear and fossil and solar plants. That's in pumps and valves. It's been 20 years since any significant work has been done.

We are now eclipsed by about 15 years by Japan and France. They achieve high reliability by virtue of quality and balance-of-plant component supply, and that's where they are putting their money.

Also extending the life of those 120 plants by improved reliability makes inordinate economic sense. It would, in fact, extend the value on your current capital investment, and it would avoid large capital construction costs in the future.

Some would challenge, you know—and I want to now address the future of the new plant options—some would challenge the wisdom of another round of improved PWR's and BWR's, based largely on the judgments that the legacy of current conditions surrounding those 120 plants preclude the LWR option from being accepted. Others would challenge the wisdom of adopting new primary-coolant technology, based largely on the experience that a new technology carries with it the risk of hidden costs in industrialization and hidden costs from delays while establishing public confidence and a new regulatory fabric.

It is our judgment that it is premature in the near term for a declaration of a Federal R&D commitment choosing one path over the other. That's not a decision, however, that should be deferred indefinitely. But what we do believe very strongly is that it is important now, before making a choice, to consider how the current de facto U.S. nuclear energy policy might be redefined or reaffirmed and how the goals of that policy might be attained with greater public acceptance and with improved plant economics and safety.

The majority of today's political leaders conclude that the advocacy of nuclear power in its current form is a liability. The nuclear industry has confidence in the safety of the present plants and their potential economic viability, and understandably they're trying to protect their investment. But I have yet to see a utility executive who is willing to go on record as saying at the present time that he would place new orders until they can be built predictably within budget and on schedule; they can be operated and maintained to achieve substantially greater availability, economic viability; and certainly that they are acceptable to the public.

The comment of one utility executive to me is that "They're more trouble—they're more damned trouble than they're worth, and what was delivered is not what was promised. We're going to need them in the future, but I can't afford them right now." And I think that's a pretty strong statement of the present situation, and we've got to correct it if we're going to move ahead.

As we near the end of the first nuclear-electric power era and contemplate a possible second era, it is worth considering now, in the Nation's interest, how the U.S. policy on commercial nuclear electric power might be redefined and the goals attained, as I said before, with less difficulty.

I will not elaborate, but I am proposing that we need a critical reexamination of the agenda we presently have, leading to reaffirmation or redirection, and that that reexamination and reaffirmation or redefinition be conducted by a commission of some sort of respected citizens, scholars, and industrialists, that lays a firm platform on which we move through the future to avoid repeating the problems we have of the past.

In conclusion, I would summarize that it is Sandia's position that the current program is insufficient to ensure that nuclear-electric power will be preserved and strengthened as an option. To preserve and strengthen the option, the program should focus on improving plant reliability, and I underline that. The future economic viability and acceptance of the first 100 plants should be our first priority.

The key observation is that the reliability and economic and safety performance of these plants, the 120, will dominate the public's perception of nuclear-electric power through at least the first quarter of the 21st century. The investment in reliability of the present plants, in my opinion, is a premium on an insurance policy that provides the insurance that there will be a second era. There will not be a second era if we have poor economics in the first plants and if we continue to have the problems that are attendant incidents, minor accidents, precursors to accidents due to unreliability.

Mrs. **Lloyd**. Well, isn't that the responsibility of the utilities and the private sector?

Mr. **Snyder**. I could make that argument. But what I am saying is that I don't think that that is going to come in and of itself without some support and encouragement from the Federal Government.

I would comment that I have an ongoing dialogue with the Electric Power Research Institute, with the nuclear steam supply system vendors, and the component suppliers over developing, by using preexisting technology to achieve higher reliability. I think that that will move much more rapidly if there is a concerted emphasis by the Congress and some modicum of support for that type of effort, which isn't there at the moment. And we're not talking about a significant fraction of the budget, but I think, in fact, it is money in earnest that that's the way to go.

Mrs. **Lloyd**. Thank you.

Mr. **Snyder**. That's the best summary that I can give, and you have the more lengthy statement.

Thank you very much.

Mrs. **Lloyd**. Thank you, Mr. Snyder.

Dr. Till, please proceed.

[The prepared statement of Mr. Snyder follows:]

Views on Federal Research and Development in Support of Civilian Nuclear Energy

- Goals and Directions
- Options for the Future

Testimony before the
Subcommittee on Energy Research and Development
Committee on Science, Space, and Technology
U. S. House of Representatives

by

A. Wm. Snyder
Director, Exploratory Nuclear Power Development
Sandia National Laboratories
Albuquerque, New Mexico

March 16, 1988

INTRODUCTION

On behalf of Sandia National Laboratories I appreciate this opportunity to express our views on current federal research and development in support of civilian nuclear energy. Our desire to present our views stems from a concern that the future viability of nuclear fission energy, as an option among the primary energy sources for the generation of electrical energy in the U.S., is tenuous and that insufficient steps are being taken to preserve and strengthen the option in the national interest. Since the options for electrical energy generation, using affordable, indigenous, sustainable, and adequate primary sources, are only coal and uranium, the viability of both needs to be fully developed and sustained. Our desire to present our views stems further from a conviction that we can and should reestablish the U.S.'s preeminence in nuclear-electric power and should support it with a modified agenda for civilian nuclear energy research and development. We observe that the U.S. has been preeminent in developing the technology of the reactor part of nuclear-electric power plants. We believe that correspondingly the U.S. should become preeminent in the development of the technology of the non-reactor balance of nuclear-electric power plants in order to support the design and construction of plants that will be an optimum national electric energy option and an international commercial asset.

We hold as basic tenets of our views

(1) that it is vitally important to attain improved and sustained public support for nuclear power by an unrelenting effort to achieve excellence in the design, construction, operation, and

maintenance of nuclear-electric power plants and nuclear fuel cycle facilities;

(2) that it is vitally important to pursue aggressive development and applications of targeted technologies that are requisite to attaining economic viability and enhanced safety in present and future nuclear-electric power plants;and

(3) that as we end the first nuclear-electric power era, based nearly exclusively on light water reactor technology, and before becoming irrevocably committed to a second era, it is in the nation's interest to reexamine the current de facto U.S. policy on commercial nuclear-electric power, how it might be redefined (or reaffirmed) and how the goals might be attained with greater public acceptance and with enhanced plant economics and safety.

I will address and provide arguments to justify these basic tenets and propose a modified agenda of research and development with the vision of recapturing for the future the intrinsic benefits of nuclear fission energy. Much of what I will propose is already contained in the Department of Energy's FY 1989 nuclear fission energy research and development budget request. That which is not in the budget derives from Sandia's views on what should be the vision and goals for nuclear energy and what is the current condition of nuclear-electric power in the U.S.

TAKING STOCK

In a period of thirty years nuclear fission energy has been developed and industrialized in the U.S. to generate eighteen percent of our nation's electric energy demand, or alternatively, to supply six percent of our primary energy consumption. It's a substantial contribution, but as a percentage of primary energy supply, the U.S. achievement of six percent has been eclipsed by most advanced industrialized nations and regions in the world outside centrally planned economy areas. For example, the European Economic Community derives 11% of its primary energy from uranium, including France at 29%, the Federal Republic of Germany at 10%, and Spain at 10%; Japan derives 11%; and Canada derives 7%. (In the U.S. other primary sources of energy contribute as follows: oil (42%), coal (24%), gas (23%) and hydro (5%). Approximately 16% of U.S. primary energy comes from imported oil, our most significant energy import.) The relative contribution of nuclear fission energy to the U.S. primary energy supply has not fulfilled the expectations of the technical, industrial, and political leaders who were the pioneers and architects of this nation's nuclear energy program. If these expectations had been fulfilled nuclear energy today would likely be contributing 20-25% of our primary energy supply, a four-fold greater percentage than has been achieved (a supply percentage only slightly less than the French achievement) and consequently could be offsetting some of our current dependence on imported oil.

Why the original objectives and the contributions to primary energy supply envisioned for nuclear energy have not been achieved is highly debated.

Some common arguments of the technical and political advocates of nuclear energy technology are that the expectations have been thwarted by the collective consequences of unjustifiable requirements that nuclear power be essentially risk-free, of excessive and undisciplined safety regulation and of active intervention. Some common arguments of the utilities, the users of the technology for electric power generation, are that the expectations have not been achieved due to reduced growth in demand, protracted construction schedules and the consequent costs, and the unpredictability of authorizations to operate. The usefulness of these arguments and observations in formulating an R&D program to revitalize the nuclear energy option is marginal, since they fail to distinguish between the symptoms and the underlying causes of the current condition of nuclear-electric power. Continued arguments to fix blame for the current condition will not improve public acceptance, it will not improve availability, it will not settle the quarrelsome safety debates, nor will it make nuclear-electric plants a more attractive option to utilities. We need to understand first and foremost what technical features of current plants and what legacies of institutional features, such as regulation, are the root cause of the current conditions that are stalemating achieving the intrinsic benefits of nuclear energy and that are an impediment to advancing into a second nuclear-electric power era.

The future of nuclear-electric power in the U.S. should consist of two parts: (1) a viable legacy of approximately 120 plants when all plants now operating and under construction are then operating; and (2) the plants of the future, plants with possibly different primary coolant technology, size, design, and managerial/institutional operating structures. But a necessary condition of a viable future is finding the means, institutionally and technically, to improve the legacy of the "120" plants of the first nuclear era.

IMPROVING THE LEGACY

It is most unlikely, and an unwarranted policy gamble with our future energy security, that the current causal conditions impacting the viability of commercial nuclear-electric power in the U.S. can be resolved solely by legislation on regulatory reform to assure a viable second era of nuclear power. Certainly, the regulatory environment needs to be cleansed of those features that appear to have the effect of making a virtue of indecision. But a fundamental goal for the first "120" plants should be to correct the causal conditions that have contributed to the symptoms of the current condition, some of those symptoms being relatively poor average availability of current plants; lingering anxiety over the safety of plants; and complex, technical regulatory issues. The common cause of most of the current symptoms is relatively poor plant reliability. Part of the evidence to justify a revamping of the regulatory environment must rest with a demonstration that significant progress is being made in improving the reliability of plants. The complexity of predicting the behavior of an unreliable plant is grist for the regulatory mill and an arguable reason for temporizing on decisions. The utility industries' commendable efforts to achieve excellence in operations and hence to improve reliability should be aggressively supported. But quality of operations is only one of the keys to a greater viability of nuclear-electric power plants. Equally important keys to achieving optimum reliability of plants are improved plant designs, improved balance of plant and other non-nuclear component designs, and improved maintenance methods and management. In existing plants, plant design (or more correctly redesign) is limited by the practical constraint of justifiable costs to retrofit to achieve the economic and safety benefits from improved reliability. Component design (and redesign) is less limited by practical constraints. Benefits from improved reliability can be attained during planned outages through retrofits of components and parts thereof. The reliability improvements attainable through improved maintenance methods and management have been amply demonstrated and documented. Thus, it is our view that the fundamental goal of the federal effort on civilian nuclear-electric energy should be to focus greater resources and commitment on attaining, in concert with the nuclear system and component supply industry, greater reliability of the first generation of nuclear-electric power plants. Principal emphasis should be placed on improving and sustaining the intrinsic reliability of those nuclear-electric power plant components derived from (or based upon) non-nuclear technology. Objective analyses of the origins of the limitations on plant reliability identify components such as pumps, valves, and non-nuclear instrumentation as the major contributors to reduced availability and to undesirable challenges to engineered safety systems. While the nuclear technology of the fuel, core design, shielding, and instrumentation of the core has been first-rate and a preeminent contribution of the U.S. to nuclear-electric power worldwide, the non-nuclear technology supporting the attainment of quality and reliability requisite to optimum economic viability and enhanced safety, both real and perceived, has been poorly supported by government. Substantially upgrading the quality/reliability of the non-nuclear technology and components of nuclear power plants will substantially improve the legacy of the first nuclear era and contribute to a greater assurance that the second nuclear era will be enhanced in quality to the benefit of greater economic viability and safety.

Extending the useful life of the first "120" plants makes inordinate economic sense through continued return on the current capital investment and by avoiding the very large costs of new construction. Utility motivation and perhaps NRC authorization to extend the licensed life of a plant will be significantly dependent upon the quality of the plant cumulative operating history and hence dependent, in part, upon the plant record of reliability. Thus, an investment now in improving the reliability of the current plants will pay the additional dividends of improving the attractiveness of extended licensed life and deferring partially the need for new construction.

CHOOSING AMONG FUTURE NEW PLANT OPTIONS

The de facto plan for the second part of the future, the plants yet to be built, has been stated succinctly by the nuclear industries' principal publication, Nuclear Industry, as follows:

> "Anticipating reopened order books in the next decade, (U.S.) industry groups strive for better, simpler, cheaper PWRs and BWRs. Radical new concepts lie in the realm of R&D for the 21st century"
>
> -Nuclear Industry, Vol. 23, No. 10, October 1986

Challenges to the wisdom of another round of improved PWRs and BWRs are based largely on judgements that the legacy of current conditions surrounding the first "120" plants preclude the option from being accepted.

Challenges to the wisdom of adopting one or more new primary coolant technologies ("radical new concepts") are based largely on the experience that a new technology carries the risk of hidden costs in industrialization and hidden costs from delays while establishing public confidence and a new regulatory fabric. It is, in our judgement, premature in the very near term for a declaration of a federal R&D commitment choosing one path over the other. But it is very important now, before making a choice, to consider how the current de facto U.S. policy on commercial nuclear power might be redefined, or reaffirmed, and how the goals of that policy might be attained with greater public acceptance, and with improved plant economics and safety.

The majority of today's political leaders conclude that the advocacy of nuclear power in its current form is a political liability. The nuclear utility industry, confident in the safety and potential economic viability of nuclear power and understandably striving to protect its capital investment and the energy production capacities of existing nuclear-electric plants, is committed to nuclear power but asserts nonetheless that it will not place new orders until plants can be built predictably within budget and on schedule, can be operated and maintained to achieve greater average availability and economic viability, and are more acceptable to the public. As we near the end of the first nuclear-electric power era and contemplate a possible second era, it is worth considering in the nation's interest how the U.S. policy on commercial nuclear-electric power might be redefined and the goals attained with greater public acceptance and with improved plant safety and economics. It is worth considering optional future courses for nuclear power, acknowledging that nuclear-electric power has no manifest destiny, that current and future realities likely preclude powerful politically supporting coalitions, and that the electric utility industry has no obligation to help fulfill the potential of nuclear energy by ordering nuclear-electric plants. Accepting these realities, it is time to chart a renaissance for nuclear power as a viable option in the interest of the nation based upon a critical assessment of the current technology and the economic and political realities of the 1990s and beyond.

Therefore, the initiation and support of a critical reexamination of the contemporary U.S. nuclear power agenda is proposed, leading to a reaffirmation or a redefinition of the future directions for nuclear power development and utilization. The reexamination would entail

- a critical review of the legacy of assumptions which have been and are the current foundations of U.S. nuclear power policy and development;
- a review of the decisions of the 1960s and 1970s that have molded the present technical and institutional character of U.S. nuclear power, decisions that are, debatably, at the root of some of nuclear power's contemporary problems; and
- an identification of technological and institutional directions and initiatives which might have avoided creating the conditions that now seriously jeopardize the potential of nuclear power as a contributor to our national energy security.

The reaffirmation or the redefinition of the future directions of nuclear power development in the U.S. would entail

- a critical comparative analysis of practical technological and institutional options for nuclear power development that could define nuclear power's role as a viable option for the nation's energy future, and
- the formulation and endorsement of policy options that could guide the nation's nuclear power development on a course that could attain the benefits that remain intrinsic to nuclear energy.

The reexamination and reaffirmation/redefinition of the U.S. nuclear power agenda should be conducted by a commission of respected citizens, scholars, and industrialists who collectively can represent broadly society's contemporary concerns and expectations from nuclear power. The communications from the commission are tentatively assumed to be a published report and synopses for publication in selected newspapers and journals. The several communications would be written for the audiences of industrialists, legislators, executives, academicians, and the general public.

FEDERAL R&D/CIVILIAN NUCLEAR ENERGY

-Critique and An Alternative

Sandia National Laboratories concludes from its review that the Program is insufficient to ensure that nuclear-electric power will be preserved and strengthened as an option in the national interest. To preserve and strengthen the option, the Program should focus on improving plant reliability. We urge that an incisive reexamination be conducted of the causal factors of the current conditions and that the Program be modified, amended, and refocused accordingly.

The future economic viability and acceptance of the first "120" plants should be the first priority. The reliability and economic and safety performance of these plants will dominate the public's perception of nuclear-electric power thru at least the first quarter of the 21st century. Their reliability and performance is a prerequisite to a future of improved new light-water-reactor designs and/or plants based on new reactor primary coolant technologies in the 21st century. Deficiencies in technology now limiting the reliability performance, and hence potentially the economics and safety, do not reside in the reactor per se, but reside in the non-nuclear systems and components of the nuclear-electric power plant.

The goal of exploring the feasibility and practicability of advanced nuclear systems with the potential for substantial improvements in economics, safety, and licenseability should be continued in the near term, but concurrent with a critical reexamination of the current nuclear power agenda. The reexamination should lead to an affirmation of current directions or redefine the agenda and policies for federally support R&D in civilian nuclear power.

We recognize that these views depart from the conventional wisdom. We offer as a defense that the conventional wisdom has become so stereotyped by dwelling upon symptoms of the current condition that we are failing to recognize where investments in nuclear energy R&D will have its greatest impact in preserving and strengthening the nuclear energy option.

STATEMENT OF DR. CHARLES E. TILL, ASSOCIATE LABORATORY DIRECTOR, ENGINEERING RESEARCH, ARGONNE NATIONAL LABORATORY, ARGONNE, IL

Dr. TILL. Thank you, Madam Chairman, and I am very grateful for your invitation to appear today.

Madam Chairman, we strongly support the directions of the Advanced Reactor Program contained in the Fiscal Year 1989 budget. We believe that the budget submission reflects an increasing resolve on the Department of Energy's part to direct its Advanced Reactor Program toward real advances in reactor technology, and we feel that such advances are both necessary and possible today.

Clearly there is an element in self-interest in this. It's been the Integral Fast Reactor development program at Argonne that provided the new directions to the program, and this year's budget submission, as stated by Dr. Bunch, for the first time places the full support of the Department of Energy behind the IFR program.

It's been, I believe, though, the extent of the technical advances in the program in just the past few years that made the decision to adopt these directions, I believe, almost inevitable, and I just want to tick through briefly the accomplishments in the program in the past year.

In the new metallic fuel, the lead assemblies had passed 10 percent last year. They have now achieved fully 15-percent burnup. The fuel behaves superbly in the reactor. There have been no failures. 15-percent burnup with the first assemblies out of the box, I think, is a very solid technical accomplishment.

In the new fuel cycle process, you may recall that the IFR process requires drawing uranium and plutonium out of some 90 other elements in one step. Last year at this time, we'd demonstrated the technical feasibility on a few-grams scale. In this past year, we've moved to routinely transferring 10-kilogram, 25-pound amounts, which amounts to be practical for an operating reactor. To do this by a totally new process in just these few years again, I believe, is a very solid technical accomplishment.

In the area of safety, the IFR fuel, as I mentioned earlier, has been remarkably immune to unexpected failures. It has reactivity characteristics that give it great margins. It does allow designs, as was demonstrated in the EBR-II tests, that allow reactors to survive potentially very serious accidents. And even if the fuel does melt for any reason, the characteristics of the metal fuel interacting with the sodium are such that no significant forces are generated.

Now we've shown all of these things in this past year or two, and again I believe that these are remarkable technical advances in such a short time.

So my point in this is that the technology underlying these decision is real. It's not just paper; it's not theorizing. We've been demonstrating these things year-by-year, and I have been able to report substantial advances to the Committee each year. I've testified—the progress is satisfying, because it's leading to a new reactor system that I think can have the characteristics needed for a new generation of nuclear power.

The IFR program is a development program, and it's the right program, I think, for the times. The lack of present commercial plant orders, the reluctance to finance large construction, and the need to curtail Federal expenditures suggest that the R&D mode is the best one for today. And if we can, through this R&D, develop a truly-improved reactor product, the Nation's resources will be well spent.

This is really the first time since the beginning of nuclear power that there has been an opportunity to carry out R&D that's radically different from other directions. Nuclear commercialization came on fast and froze the early decisions and the early designs in place. We have the opportunity now, and it's a real opportunity, if we take advantage of it. It's also a relatively inexpensive program, of course, compared to the construction of large machines.

So for all these reasons, we strongly support the DOE program, and recognizing what the program is and what it's accomplished and what it promises, I hope that the Committee will support it as well.

Now the two things that we want to accomplish over the next year, the two main things, the first is to get on with the modifications to the EBR-II complex, to install the new processes, so that we will be able to turn the fuel around, process it, and return it to the reactor—demonstrate the whole fuel cycle.

And the second one is to provide large amounts of metal fuel to FFTF for its future fueling.

For those two things, because of the added scope to the Argonne budget, we need about $4 million for the HFEF modification and about $2 million for the FFTF fuel manufacture. What we'll be doing in the latter case is adding sufficient technicians to push the fuel manufacture through the fuel manufacturing facility at Argonne-West.

If the Congress, if the Committee, finds themselves able to grant those requests as additions, I believe it would be a prudent and wise expenditure of national resources.

But in any event, Madam Chairman, I thank you and the committee for this opportunity to speak to you today.

Mrs. LLOYD. Thank you very much, Dr. Till.

Dr. Arnold?

[The prepared statement of Dr. Till follows:]

TESTIMONY

PRESENTED TO THE SUBCOMMITTEE ON
ENERGY RESEARCH AND DEVELOPMENT
OF THE
HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

March 16, 1988

CHARLES E. TILL

Associate Laboratory Director,
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Statement of

Charles E. Till

Associate Laboratory Director
Engineering Research
Argonne National Laboratory

To the

Subcommittee on Energy Research and Development
of the
House Committee on Science, Space, and Technology
U.S. House of Representatives

March 16, 1988

Madam Chairman, members of the Subcommittee, I am Charles Till, Associate Laboratory Director for Engineering Research, Argonne National Laboratory. I am responsible for Argonne's Reactor Development Program. Once again I am grateful to this Committee for your invitation to appear today to present our views on the directions of the reactor development program contained in the Department of Energy FY 1989 budget.

Madam Chairman, we strongly support the directions of the advanced reactor program contained in this budget. We believe that the budget submission reflects increasing resolve on the part of the Department of Energy to direct its advanced reactor programs toward real advances in reactor technology. Today such advances clearly are necessary, and, just as clearly, are possible.

It has been the Integral Fast Reactor development program at Argonne that has provided the new directions to the program. This year's budget submission, for the first time, places the full support of the Department of Energy behind the IFR program. The extent of the technical advances in this program in just the past few years made the decision to adopt these new directions, I believe, almost inevitable.

The IFR concept is based on two simple premises. First, the heart of the breeder reactor, any breeder reactor, is its fuel cycle. The fuel cycle must be developed along with the reactor itself and optimized as an integral part of the whole reactor system. (This, by the way, was the origin of the name Integral Fast Reactor). Second, any advanced generation of reactors must be developed with explicit characteristics that would allow it to meet the very large energy demands of the future. If not, development of a new generation of reactors is just not likely to be worthwhile. Meeting total future energy needs means deployment of thousands, or tens of thousands of reactors. Among the implications of this is that the new generation should be extraordinarily safe, so that the statistical probability of accident in the aggregate remains small. The safety aim should be as close to foolproof as it is possible to make them.

These thoughts led to the two major technological changes in direction mbodied in the IFR. Both, in our opinion, were necessary to make such ystems possible. The two innovations were the replacement of oxide fuel with new metallic fuel form, and the replacement of conventional reprocessing ith a radically new process for reconstituting spent fuel right on the eactor site. Both were totally new and required development. That evelopment has proceeded swiftly and successfully at Argonne National aboratory. I think it best to briefly describe this progress, for it is hese real and tangible scientific accomplishments that underpin the new rogram.

1. **The New Metallic Fuel:** Reactor fuel must be capable of high urnup -- capable of staying in the reactor without failure for two, three or ore years. To give some perspective, conventional LWR fuel burns about 3% of ts contents, oxide breeder fuel 10% or more, whereas early metal fuel -- when evelopment was stopped 20 years ago -- would burn up only 1 or 2%. The new etallic fuel had passed 10% burnup last year when I reported to this ommittee. It has now achieved fully 15% burnup. The fuel performs superbly n-reactor, thus opening the way to all the advantages that follow from the se of this type of fuel. Fifteen percent burnup in the first fuel assemblies ver made with this type of fuel, the first out of the box, if you like, is a olid technical accomplishment.

2. **The New Fuel Cycle Process:** Conventional reprocessing is large-cale and expensive. Metallic fuel allows electrochemical processing which is ntrinsically small scale, and promises even to be economic at very small cale. To give perspective, forms of electrochemical processing are used in efining in the metals industries, and in some other metallic refining perations where trace impurities are removed, so electrorefining itself is ot new. But the IFR process required uranium and plutonium to be removed rom the ninety other elements present in spent fuel in a single step and with ufficient purity to make the fuel fresh again. Science said it was easible. Last year at this time we had demonstrated technical feasibility on few-gram scale. This year we are routinely transferring ten kilogram mounts of uranium, almost full-plant scale. To move from theoretical ossibility to transfers of 10 kilograms, 25 lbs, amounts that would be ractical for an operating reactor, by a totally new process in just these few ears is also a solid technical accomplishment.

3. **The New Safety Characteristics:** The new IFR fuel has proven to be emarkably immune to unexpected failures, it has reactivity characteristics hat give greater safety margins, it allows IFR designs that survive even the ost serious accidents that can befall reactors -- the so-called ATWS or nticipated Transient Without Scram events, and, even if the fuel did fail or elt, its characteristics are such that no significant forces are generated. described the exciting EBR-II safety demonstration last year. But all these haracteristics have now been identified, analyzed, and experimentally erified. To demonstrate such a full range of improved safety haracteristics, some of them truly radical advances, in this time again is olid technical accomplishment.

This new technology is real. It is not just paper, or theorizing. It has been proven by experiment and by demonstration year by year. A mark of this is that I have been able to report substantial advances to this Committee each year I have testified. Such progress is deeply satisfying.

The progress is leading to a new reactor system that can have the characteristics needed for a new generation of nuclear power. More foolproof safety, economic promise, closed fuel cycle, high uranium resource utilization, reduced volume waste with very long-lived radioactive isotopes removed, improved fissile material diversion characteristics, no yearly transport of fissile material to or from the plants; the list could go on. Our nation would be well served by this kind of a reactor system. With these characteristics it will supplant present systems, as well as other advanced reactor options, and assure the U.S. of a dominant international position in nuclear power in the future.

The IFR program is a development program and it is the right program for the times. The lack of present commercial nuclear plant orders, the understandable reluctance of both the public and private sectors to finance large new construction, and the need to curtail federal expenditures all suggest that this R&D mode is the best option today. If, as I have suggested, R&D truly can develop a reactor system that because of its greatly improved characteristics, will reopen the immense energy needs of the future to nuclear power, the nation's resources will have been well spent.

For nuclear power will be needed eventually, and needed in vast amounts. That eventuality, I believe, is inevitable. There is nothing comparable in magnitude to it and some public polls even today seem to recognize the certainty of its eventual need. Now is the time for the R&D. In fact this is the first opportunity since the very early days of nuclear power development to make radical changes and improvements to civil reactor systems. Nuclear reactor commercialization came on very fast, and in effect froze the early choices in place. We must wisely use this time for R&D.

The R&D stage is also relatively inexpensive, if properly managed, compared to construction of large machines. The whole R&D program that will develop the entire reactor system; reactor, fuel cycle, waste processes and all; is done at Argonne National Laboratory. It requires about $80M per year. The product is an entirely new advanced reactor technology. That amount supports the facilities required; it supports a base of top-flight technogical expertise in all reactor-related disciplines -- not an unimportant fact from a national point of view, as it is the only one left in the country; with DOE and NSF support Argonne will be moving progressively to buttress university nuclear engineering programs with our complete spectrum of reactor system development work, providing the nation with young, trained talent and expertise; and, finally and most importantly, once again, a new radically improved reactor system is being developed.

For all these reasons we strongly support the DOE program. Recognizing what the program is, what it has accomplished, and what it promises, I hope this Committee will strongly support it as well.

The two biggest items in the development program coming up in FY 1989 are, first, the continued rapid, low-cost modification of the EBR-II complex at ANL-W to house the new IFR fuel cycle processes and bring them into operation at plant-scale size, and second, the large-scale manufacture at ANL-W of new metallic fuel to fuel FFTF in the future. An additional $4M for FY 1989 is needed for the first, and $2M for the second. If granted, these amounts will allow the entire IFR demonstration on schedule in 1990, and fuel to be supplied to the FFTF so its lifetime will not be limited by lack of fuel.

I believe both are strongly in the interest of the program and the $6M addition would be a prudent and wise expenditure of resources.

Madam Chairman, I thank you and the Committee for this opportunity to speak today.

STATEMENTS OF DR. W. HOWARD ARNOLD, VICE PRESIDENT, ENGINEERING AND DEVELOPMENT DIVISIONS, WESTINGHOUSE HANFORD CO., RICHLAND, WA; ACCOMPANIED BY DR. MICHAEL K. KORENKO, GENERAL MANAGER, ADVANCED REACTOR DEVELOPMENT DIVISION

Dr. ARNOLD. Madam Chairman, Members of the Subcommittee, I'm pleased to be here once again this year discussing the progress made at Hanford in numerous areas important, I believe, to DOE's programs.

I have with me Dr. Michael Korenko, who has actual responsibility for the programs we'll be discussing. We're going to discuss programs in three areas: FFTF as it supports the vision of a future liquid metal reactor, the expanding role as a national irradiation test center and our contributions to space power, some of which were already discussed today.

But let me introduce Mike Korenko.

Dr. KORENKO. Thank you.

In the interest of time, I may omit sentences and paragraphs here, but I'd like to put the whole statement into the record.

Mrs. LLOYD. Your entire statement will be made a part of the record. I realize that we've kept you very late, so we'll be happy if you summarize.

Dr. KORENKO. We have no flights tonight—I can't speak for you, Chuck.

I'd like to start with reporting our progress in achieving the vision of a deployed liquid metal reactor. The reactor of the next century must be competitive in terms of safety, economics, proliferation, resistance and waste reduction. I believe the LMR will offer major incentives in each of these areas if we focus our R&D efforts wisely.

First, the reactor of the future must be inherently safe, such as the basic physical principles will drive the reactor to benign conditions. The initial safety tests conducted at FFTF and EBR-II were a world-class achievement. We regret that the critical follow-on tests were unfunded this year, however we will need to complete the final inherent safety testings in FFTF in 1989 and 1990 before our transition to the all metal-fuel core, before we go from an oxide to a metal character.

The final phases of this are crucial to eventual deployment, as this is the only facility capable of the prototypic scale testing.

Secondly, the future reactor must be economically competitive. It's important to focus on reducing both capital and operating costs. Progress to the current innovative design effort is very encouraging. Modular plants greatly simplified to current reactors will reduce the construction and licensing costs.

Now, there are three areas for demonstrating the lower operating cost of the LMR's. The first is trouble-free plant operation. For example, the FFTF's performance. Secondly is the long-life cores, as demonstrated by the Core Demonstration Experiment.

And thirdly, the centralized fuel cycle facilities, such as the PUREX process at Hanford.

FFTF's superb operation demonstrates an essential element of the economic competitiveness. The FFTF is the only U.S. DOE reactor that has undergone the independent regulatory scrutiny normally expected of commercially operating reactors by the NRC staff. Therefore, the performance of the FFTF becomes of great interest to the U.S. in the international nuclear power community.

I am delighted to report that the FFTF achieved 100 percent operational efficiency factor during all of 1987, and also achieved a 76.5 percent plant capacity factor, which is excellent for any reactor.

The long-life cores are important to reducing plant operating costs. This month, FFTF fuel assembly demonstrated a burnup of 160 megawatt-days per kilogram metric. That's a very clear world record. At this time the Core Demonstration Experiment has achieved one-half of its goal exposure of three years and the lead tests in that experiment have achieved up to 75 percent of the goal exposure.

The examination confirms the non-swelling character of the HT9 steel.

Collectively, this information supports the high expectation that an LMR fuel system, having a three- to four-year lifetime, will be fully demonstrated by 1990. Achievement of this goal reduces the future fuel-cycle cost for the LMR's by a factor of three, compared to that for the initial LMR fuel design.

In addition, the first two of the 17 protype uranium-zirconium metal FFTF assemblies will start irradiation toward a goal burn-up of 140 megawatt-days per kilogram this year. This metal fuel has the promise of demonstrating yet lower costs.

A third feature of the successful LMR reactor of the future is proliferation resistance. That is, resistance to diversion and misuse of nuclear materials.

I'd just like to point out the simple fact that while fuels are in these long-life cores they are not accessible for diversion.

Finally, the LMR reactors of the future could potentially contribute to the reduction of their high-level radioactive waste, as well as the waste from the LWR's. It's important not to over-inflate these claims since we do not yet have the proven technology. Yet, the correct next step is a two-year study with many demonstrations in FFTF and FMEF. But two recent technological breakthroughs, TRUEX in the epithermal columns and LMR's, have raised their expectations. Theoretically, one LMR reactor could burn the actinides from a significant number of LWR's.

So, collectively there is a vision that achieves the objectives of safety, economics, proliferation resistance and waste reduction for the reactors of the future.

The second topic I'd like to address is the diversification of FFTF.

Over the last four years, Hanford has been expanding FFTF's use by the nuclear community and I'd like to point out four areas in which we've made some progress last year.

First, the fusion testing program in FFTF is greatly increased. They have just signed an international agreement for an eight-year, fully-dedicated fusion materials open test assembly. This was signed by Europe, Canada, Japan and the United States. We're requested developmental funds for a low temperature test which will allow us to go into the 100- to 300-degrees C. range, which will provide valuable information necessary for the International Thermonuclear Experimental Reactor.

Secondly, last year FFTF produced some of the world's highest-purity gadolinium for the osteoporosis detectors, and we are currently analyzing how we may provide a number of other isotopes for a range of applications in this country.

Thirdly, three new tests for space power were fabricated and placed under irradiation in FFTF. Two of these tests, which are being conducted in support of SP–100, operate at a white-hot test temperature. The third test supports the multi-megawatt thermionics program.

And finally, in the fourth area, the power addition study really went very well. There were no technical or safety show-shoppers. In addition, the Japanese have shown real interest in investing a steam generator test station linked to the power addition project. The project is a triple winner. We can test some of the critical Clinch River Breeder components to gain some benefit from all those dollars that were spent. Secondly, we can lower the operating costs of FFTF, and thirdly, we can broaden our mission to include a steam system testing center.

However, negotiations must still be completed with our customer for the electricity produced. Also, DOE must indicate to the customer their continued support for planned operation.

Our final subject is our expanding role as a contributor to space power. I've already mentioned the FFTF irradiations in support of SP–100 in multi-megawatt. Secondly, the SP–100 Ground Engineering System test facility has gained momentum in preparing to test the prototype nuclear reactor flight shield and control system.

And thirdly, the Department of Energy recently selected the Fuels and Materials Examination Facility at Hanford as the preferred site for the facility needed for packaging the Dynamic Isotope Power System Supplies.

During the last year the SP-100 Program has completed the preliminary design of the test site, refurbished 75 percent of the surplus equipment being transferred from FFTF and completed the removal of the obstructions from containment in service buildings. This latter activity involved 40,000 man-hours of construction labor, with heavy loads of radiation and asbestos with no accidents and as not so much as a skin- contamination of radiation exposure.

Our current activities are focusing on definitive design with preparation of construction in equipment procurement specifications on our preparation of the preliminary safety analysis report.

Howard, do you want to close this?

Dr. ARNOLD. Thank you, Mike.

As you can see, we have made significant progress on advancing the LMR, on diversification of the FFTF resource and in supporting space power. Unfortunately, we do this just as our budget outlook is especially bleak. We're not talking here about other things that have happened at Hanford, such as the cancellation of the repository project or shut down of N-Reactor though those have an impact that we have to work hard to avoid in terms of overhead-creep which would result from a shrinking Hanford base if we don't take drastic action. But we will take care of that.

The problem we're facing is preliminary guidance for fiscal year 1989 and beyond which threaten continued support of operations at FFTF. We have more recently become aware that DOE is evaluating activities for FFTF to provide a long-term stable mission. Such an approach is absolutely necessary so that we can negotiate for the power addition and proceed with the plans for the important civilian reactor space and defense programs.

FFTF has been and is a beacon of excellence, and a very important U.S. claim of world-class status in the nuclear power industry, and we look forward to working with DOE to achieve its continued long-term operation.

Thank you.

[The prepared statement of Dr. Arnold and Dr. Korenko follows:]

TESTIMONY
BEFORE THE
U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

DR. W.H. ARNOLD
VICE PRESIDENT
ENGINEERING AND DEVELOPMENT DIVISIONS
WESTINGHOUSE HANFORD COMPANY

AND

DR. M.K. KORENKO
MANAGER
ADVANCED REACTOR DEVELOPMENT DIVISION
WESTINGHOUSE HANFORD COMPANY

MARCH 17, 1988

38803-068.1M

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CIVILIAN REACTOR DEVELOPMENT PROGRAM

AT WESTINGHOUSE HANFORD COMPANY

Madame Chairman and Members of the Subcommittee:

My name is Howard Arnold, Vice President, Engineering and Development Divisions for the Westinghouse Hanford Company. Last year I reported on our 1987 achievements and goals for 1988. This year, I'd like to introduce Mike Korenko, manager of the Advanced Reactor Development Division at Westinghouse Hanford Co. He has the responsibility for a number of facilities and programs targeted on maintaining the nuclear option for this country. He will present the oral testimony, while both of us would be happy to answer your questions.

We are pleased to have the privilege to appear before this subcommittee, and would like to focus on three areas:

(1) Our contributions to achieving the vision of liquid metal reactors which includes the record breaking performance of FFTF,

(2) Our expanding role as a national irradiation test center, and(3)Our contribution to space power.

I'd like to start with reporting our progress in achieving the vision of a deployed liquid metal reactor. The reactor of the next century must be competitive in terms of safety, economics, proliferation resistances, and waste management. I believe the LMR will offer major incentives in each of these areas if we focus our R&D efforts wisely.

First, the reactor of the future must be inherently safe, such that basic physical principles will drive the reactor to benign conditions. The initial passive safety tests conducted at FFTF and EBR-II were a world class achievement. We regret that the critical follow-on tests were unfunded this year. We will need to complete the final inherent safety tests in FFTF in FY-89 and FY-90 before our transition to the all-metal fueled core. The FFTF phases of this are crucial to eventual deployment, as this is the only facility capable of prototypic scale testing.

Secondly, the future reactor must be economically competitive. It is important to focus on reducing both capital and operating costs. Progress o. the current innovative design effort is very encouraging. Modular plants, greatly simplified compared to current reactors, will reduce construction and licensing costs. In fact, the broad commercially based innovative plant concept is on target and should continue to be supported as a long term program resource.

There are three keys to demonstrating the lower operating cost of LMRs: (1) trouble free plant operation, (2) long life cores, and (3) centralized fuel cycle facilities, such as the PUREX process at Hanford.

FFTF's superb operation demonstrates an essential element of economic competitiveness. The FFTF is the only U.S. DOE reactor that has undergone the independent regulatory scrutiny normally expected of commercially operating reactors by the NRC staff. Therefore, the performance of the FFTF becomes of great interest to the U.S. and international nuclear power community. I am delighted to report that the FFTF achieved 100% operational efficiency factor during all of 1987 and also achieved a 76.5% plant capacity factor, which is excellent for any reactor. In addition, the FFTF operated for nineteen months with no unplanned outages, and the total integrated radiation exposure received by the plant personnel was two orders of magnitude below the commercial nuclear average.

Long life cores are important to reducing plant operating costs. This month an FFTF fuel assembly demonstrated a burnup of 173 MWd/KgM--a very clear world record. At this time, the Core Demonstration Experiment has achieved one half of its goal exposure of three years and the lead tests have achieved up to 75% of the goal exposure. Examination confirms the non-swelling character of the HT9 steel.

Collectively, this information supports the high expectations that a LMR fuel system having a three to four year lifetime will be fully demonstrated by 1990. Achievement of this goal will reduce the future fuel cycle costs for the LMR by a factor of three compared to that for the initial LMR fuel design. It is both exciting and gratifying that the next two years will witness a major breakthrough in oxide fuel technology in the U.S. In addition, the first two of 17 prototype U-Zr metal FFTF assemblies will start irradiation toward a goal burnup of 140 MWd/KgM this year. This metal fuel has the promise of demonstrating yet lower cost.

The third feature of a successful LMR reactor of the future is proliferation resistance, that is, resistance to diversion and misuse of nuclear materials. While fuels are in long life cores, they are not accessible for diversion.

Finally, the LMR reactors of the future could potentially contribute to the reduction of their own high level radioactive waste, as well as the waste from LWRs. The Clean Use of Reactor Energy (CURE) proposal is targeted to achieve this benefit. It is important not to over-inflate these claims since we do not yet have a proven technology. The correct next step is a two-year study with mini demonstrations in FFTF and FMEF. Two recent technological breakthroughs, TRUEX and epithermal columns in LMRs, have raised our expectations.

Theoretically, one LMR reactor could burn the actinides from a significant number of LWRs. The TRUEX and LMR epithermal columns could then be used to separate and then to transmute the other highly radioactive waste isotopes into a more innocuous waste form.

Here is an LMR vision that achieves the safety, economics, proliferation resistance, and waste reduction for the reactors of the future.

The second major topic that I would like to report on is the diversification of FFTF. For the last four years, Hanford has been expanding FFTF's use by the nuclear community.

(1) The fusion testing program in the FFTF has greatly increased. We have just signed an international agreement for an eight-year fully dedicated fusion Materials Open Test Assembly. This materials test involves a signed agreement with Europe, Canada, Japan and the U.S. We have requested developmental funds for a low temperature test vehicle which will reach the 100° to 300°C range. This will provide invaluable information necessary for the International Thermonuclear Experimental Reactor (ITER).

(2) Last year FFTF produced some of the world's highest purity gadolinium for osteoporosis detectors. We are currently analyzing how we may provide a number of other isotopes for a range of applications in this country.

(3) This year three new tests for space power were fabricated and placed under irradiation in the FFTF. Two of the tests, which are being conducted in support of SP-100, represent a considerable extension of testing capability. Both tests are operating at 2250°F--a white hot test in our liquid metal reactor. The third test supports the Multimegawatt Thermionics Program.

(4) The power addition study went very well. There were no technical or safety show stoppers. In addition, the Japanese have shown real interest in investing in a steam generator test station linked to the Power Addition Project. The project is a triple winner. We can test some of the critical CRBR components to gain some benefit out of all those tax dollars that were spent, we can lower the operating cost of FFTF, and we can broaden our mission to include a steam system testing center. However, we still have the need to find a customer for the electricity produced. Also, DOE must indicate to that customer their continued support for plant operations.

Our final subject is our expanding role as a contributor to space power. First, we have already discussed the FFTF irradiations in support of the SP-100 and multimegawatt programs. Secondly, the SP-100 Ground Engineering System (GES) Test Facility has gained momentum in preparing to test the prototype nuclear reactor, flight shield, and control system, and thirdly, the Department of Energy recently selected the Fuels and Materials Examination Facility (FMEF) at Hanford as the preferred site for the facility needed for packaging the Dynamic Isotope Power Systems (DIPS) power supplies.

During the last year, the SP-100 program has completed the preliminary design of the Test Site, refurbished 75% of the surplus equipment being transferred from FFTF, and completed the removal of obstructions from the containment and service buildings. This latter actively involved 40,000 manhours of construction labor with heavy loads, radiation, and asbestos with no accidents and not so much as a skin contamination of radiation exposure. Our current activities are focusing on definitive design with preparation of construction and equipment procurement specifications and on preparation of the Preliminary Safety Analysis Report.

As you can see, we have made significant progress on advancing the LMR, diversification of the FFTF resource, and supporting space power.

Unfortunately, we do this just as our budget outlook is especially bleak. We are not talking here about cancellation of BWIP or shutdown of the "N" reactor--the impact of these is indirect and results in the need to avoid any upward creep in overhead costs resulting from a shrinking Hanford base.

No, the problem we are facing is verbal guidance for fiscal 89 and beyond which threatens continued support of operations at FFTF. Without some assurances from DOE, we cannot negotiate for a power addition, we cannot plan for the important civilian reactor, space and defense programs Dr. Korenko has discussed, nor will we even have fuel to continue operation of the reactor itself beyond 1991. This would be a tragedy, as FFTF has been a beacon of excellence, and one of a very few recent US claims of world class status in the nuclear industry.

BIOGRAPHICAL INFORMATION

WILLIAM HOWARD ARNOLD

Dr. Arnold has been Vice President, Engineering and Development for the Westinghouse Hanford Company, the consolidated Operations and Engineering contractor at Hanford, since June 1987. His responsibilities include FFTF, the SP-100 Ground Engineering System, other reactor development activities, and the provision of site-wide Engineering and Project Management.

For the prior six years, he was General Manager of the Westinghouse Advanced Reactor and Advanced Energy Systems Divisions, responsible for programs and projects which included liquid metal, space, and military terrestrial reactors, as well as non-nuclear systems such as fuel cells and photovoltaic power supplies.

Before 1981, Dr. Arnold's career involved a broad range of technical and management responsibilities in the energy and defense fields. He was associated with the NERVA nuclear rocket program from 1962 to 1968, directly responsible for test operations in Nevada during four successful tests, and NERVA program manager. At the Westinghouse Defense Center in Baltimore, he was Manager, Underseas Weapons Department from 1968-71. Under his direction, the development of the Mark 48 torpedo, current mainstay of the fleet, was successfully completed. Associated with Westinghouse commercial pressurized water reactor power plants from 1955-61 and from 1971-81, he became General Manager, PWR Systems Division in 1972 and President, Westinghouse Nuclear International in 1979. In these positions, he was responsible for the design, nuclear safety, and project management of 96 Westinghouse PWR nuclear steam supply systems and for technical support of an additional 76 built by Westinghouse licensees.

Dr. Arnold joined Westinghouse in 1955 as a senior engineer in reactor design after earning his doctor's and master's degrees in physics at Princeton University, and his bachelor's degree in physics and chemistry at Cornell University. He was elected to the National Academy of Engineering in 1974, is a registered nuclear engineer in Pennsylvania, and a Fellow of the American Nuclear Society and the American Association for the Advancement of Science. He was born in Jefferson Barracks, Missouri, in 1931 and married Josephine Routheau in 1952. They have raised five children, and reside in Kennewick, Washington.

BIOGRAPHICAL INFORMATION

MICHAEL K. KORENKO

As manager, Advanced Reactor Development Division, Dr. Korenko's responsibilities include: managing $110M worth of programs, approximately 550 people, and over $2B worth of facilities. This includes directing operation of the Fast Flux Test Facility, the Fuel Cycle Plant and associated fuel fabrication operations, and the SP-100 Space Power Test Site. His programs cover a wide range of activities including liquid metal reactors, fusion, medical isotope production and robotics.

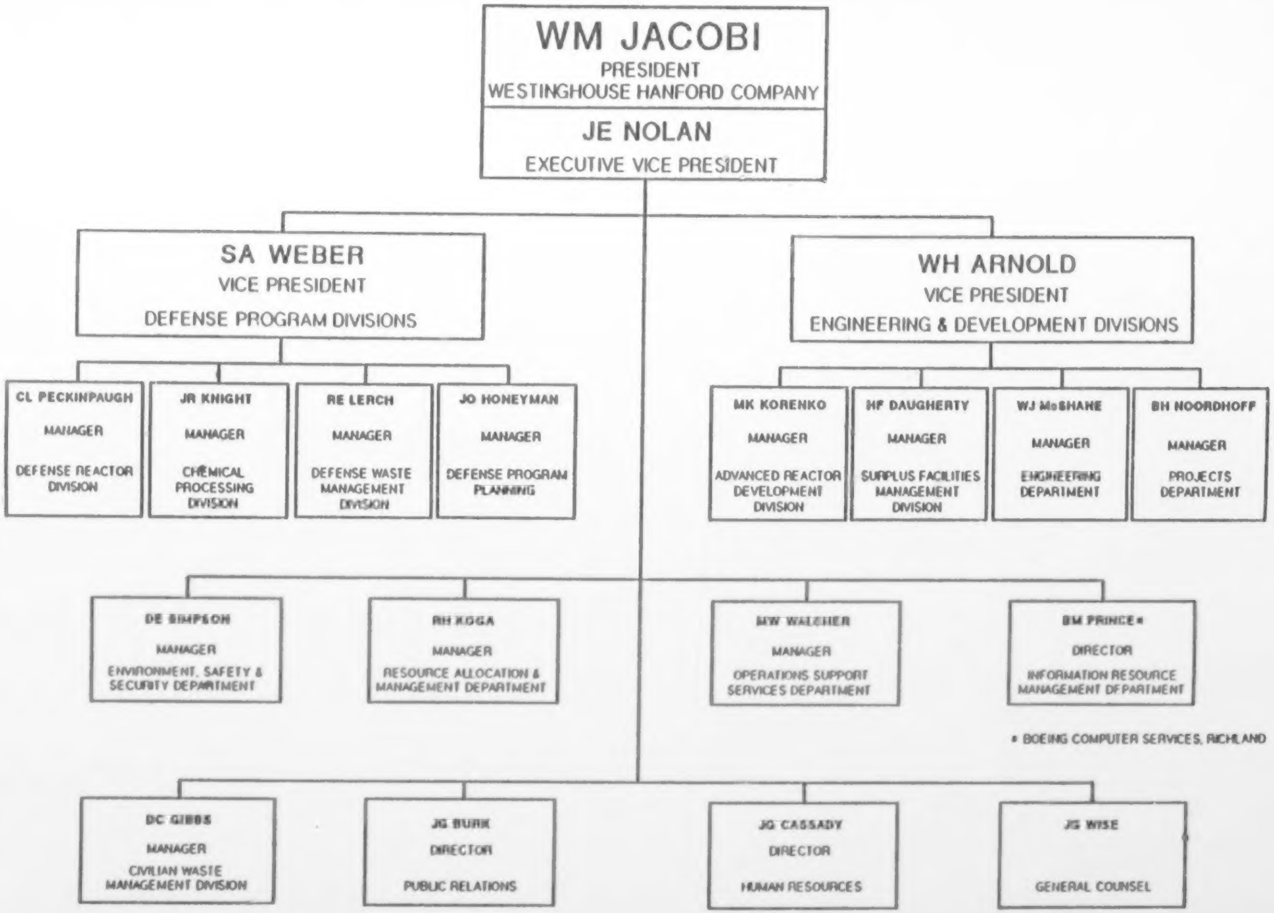
Dr. Korenko received a B.S. in Metallurgy from Case Institute of Technology; a M.S. in Materials Engineering from Case-Western Reserve University; and a Sc.D. in Materials from MIT. Dr. Korenko joined Westinghouse Hanford Company in 1974 after performing a year in post-doctoral research at Oxford University. As a scientist at WHC, he received 14 patents for advanced materials, and received the company's 1977 "Invention of Year Award."

He was selected as one of the 14 White House Fellows from among several thousand applicants in 1980-1981, and served as a staff assistant to Secretary of Defense Weinberger under the fellowship. He returned to Westinghouse and was named to a series of high-level corporate positions in Pittsburgh. Prior to returning to WHC, he was manager of business development for the Westinghouse Advanced Power Systems Division where he spearheaded the corporate thrust to transfer technology from federal laboratories to the commercial sector. He was selected as the 1983 Quality Manager of the Year. Prior to his present position, Dr. Korenko was manager of Applied Systems Development and was responsible for program diversification.

ATTACHMENTS:

1. WESTINGHOUSE HANFORD COMPANY ORGANIZATION CHART
2. WHC LMR COST/FUNDING PROFILE
3. FAST FLUX TEST FACILITY
4. FUEL AND ABSORBER PERFORMANCE
5. FFTF FUEL SUPPLY
6. SPACE NUCLEAR POWER

Attachment 1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DIRECTOR
PUBLIC RELATIONS
JG CASSADY
DIRECTOR
HUMAN RESOURCES
JS WISE
GENERAL COUNSEL

* BOEING COMPUTER SERVICES, RICHLAND

WHC LMR COST/FUNDING PROFILE

($ MILLIONS)

	ACTUAL							NEED
	FY-82	FY-83	FY-84	FY-85	FY-86	FY-87	FY-88	FY-89
OPERATING (BO)	122.7	107.7	100.2	89.6	77.7	65.8	64.0	75.2
CAPITAL (BA)	58.8	22.0	24.0	16.2	7.2	4.0	3.4	4.8
TOTAL	181.5	129.7	124.2	105.8	84.9	69.8	67.4	80.0

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Attachment 2

Attachment 3

FAST FLUX TEST FACILITY

The Fast Flux Test Facility (FFTF) is the premier irradiation test center of the world and is providing essential support to liquid metal reactor development, space energy, and isotope production programs.

The FFTF, a 400 megawatt sodium-cooled reactor, is a unique national resource with broad technology development and demonstration objectives:

- It is crucial to the development of the SP-100 space power reactor.
- It can produce needed isotopes for medical, space, and defense programs such as: ^{153}Gd, ^{242}Pu, ^{252}Cf, and ^{238}Pu.
- It can demonstrate the destruction of nuclear weapons by converting the plutonium to nuclear fuel which is consumed in a civilian reactor.
- It can demonstrate best the concepts for elimination of the need for geological repositories for nuclear waste.
- It is needed to develop, test, and demonstrate fuel systems for advanced nuclear reactors, e.g., metal fuel for liquid metal reactors.
- It is needed to develop and demonstrate the balance of liquid metal reactor plant components for electricity generation.
- It is needed for fusion materials development.
- It can serve as a technological demonstration of defense materials production in LMR.
- It is needed to maintain the U.S. partnership with the world's LMR community.

The FFTF has long been recognized as a plant run on excellence. Two indicators of operational excellence are capacity factor, and operational efficiency factor (OEF). In 1987, the FFTF surpassed its goals and achieved its highest percentages ever in both areas.

Plant capacity factor is a measure of the time the reactor is operating at rated power. The 76% capacity factor achieved in 1987 ranks FFTF among the best commercial power plants. For the years 1984-1986, FFTF averaged a 61% capacity factor which compares with 57% for all commercial plants for the same period.

The operational efficiency factor is a measure of how well operations are conducted against a pre-approved plan which includes outages for refueling and insertion or removal of experiments. In 1987, the FFTF achieved 100% OEF. A record 19 consecutive months at 100% OEF was achieved through January 1988.

In addition, the FFTF also achieved other records in 1987, including:

. No automatic shutdowns, equaling the record first set in 1984.

. No forced outages.

. 105 continuous full-power days.

The accomplishments at FFTF reach beyond these records set in operations. The FFTF continues to break its own world-wide record for peak burnup within a full sized fuel assembly. Test Assembly D9-3 reached 173 MWd/kgM burnup by the end of February 1988. D9-3 is a fuel assembly which uses an advanced steel alloy for fuel assembly components.

The FFTF also made great strides in 1987 in demonstrating its capability for isotope production. Two isotopes were produced, Cobalt-60 and Gadolinium-153. Cobalt-60 can be used for food irradiation and sterilization of medical equipment. In late 1987, the first Gadolinium-153 was sold for use in diagnostic machines that aid in the early detection of the bone-crippling disease, osteoporosis.

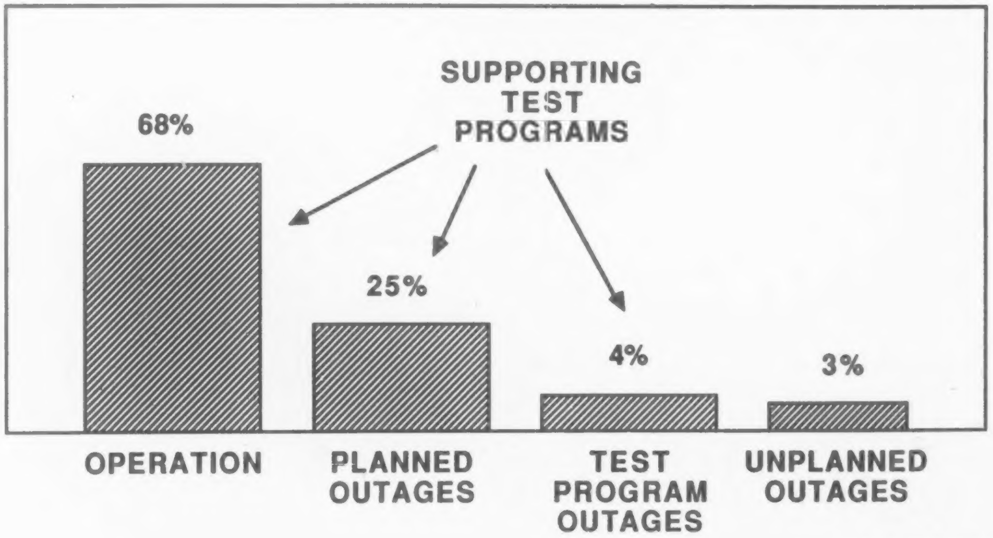
Another significant accomplishment is the completion of an advanced conceptual design for addition of utility-owned electric power generating capability to FFTF. The design confirms technical feasibility of the concept and the associated cost estimate demonstrates its economic viability.

The near-term goals for FFTF center on establishing and sustaining performance records which place FFTF among the best commercial nuclear power plants in the United States. In the longer-term, FFTF goals include electric power generation, steam generator and other LMR component testing and space power, isotope production, fusion materials, and special nuclear materials development demonstrations. The FFTF operating experience will contribute significantly to demonstration of the safety, environmental acceptability and cost effectiveness of liquid metal reactor plants of the future.

OPERATING TO SUPPORT DOE PROGRAMS

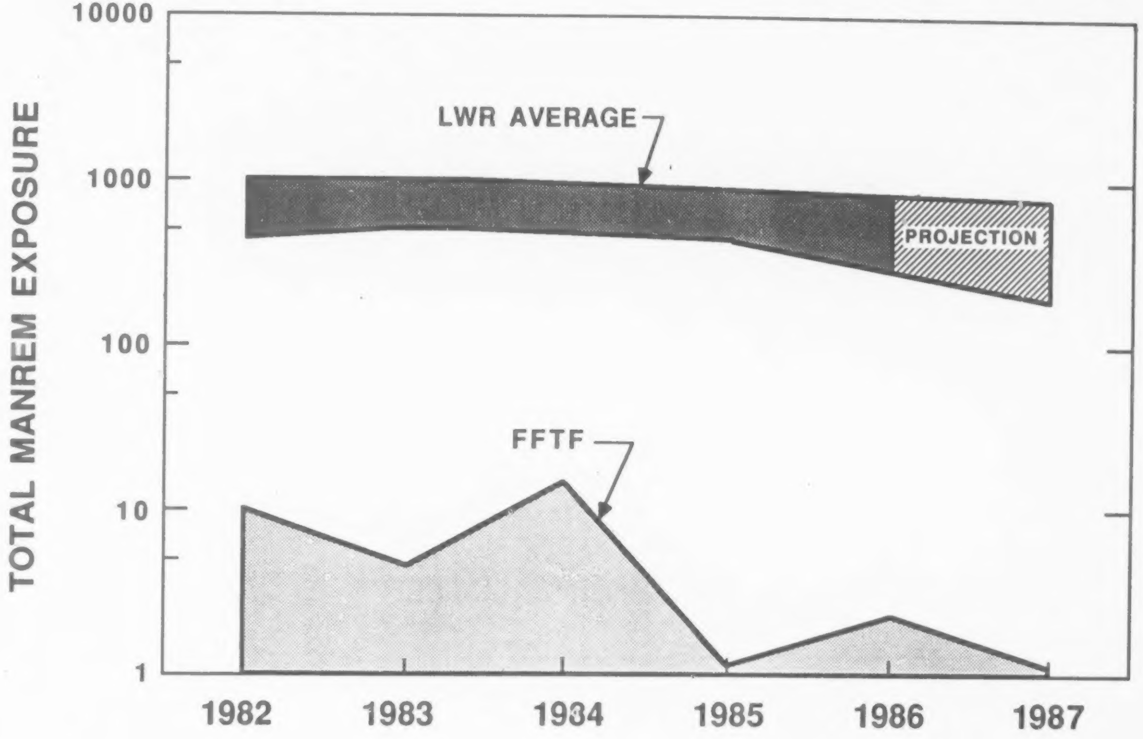
- 97% "ON MISSION SINCE 1983"

FFTF'S OPERATING HISTORY

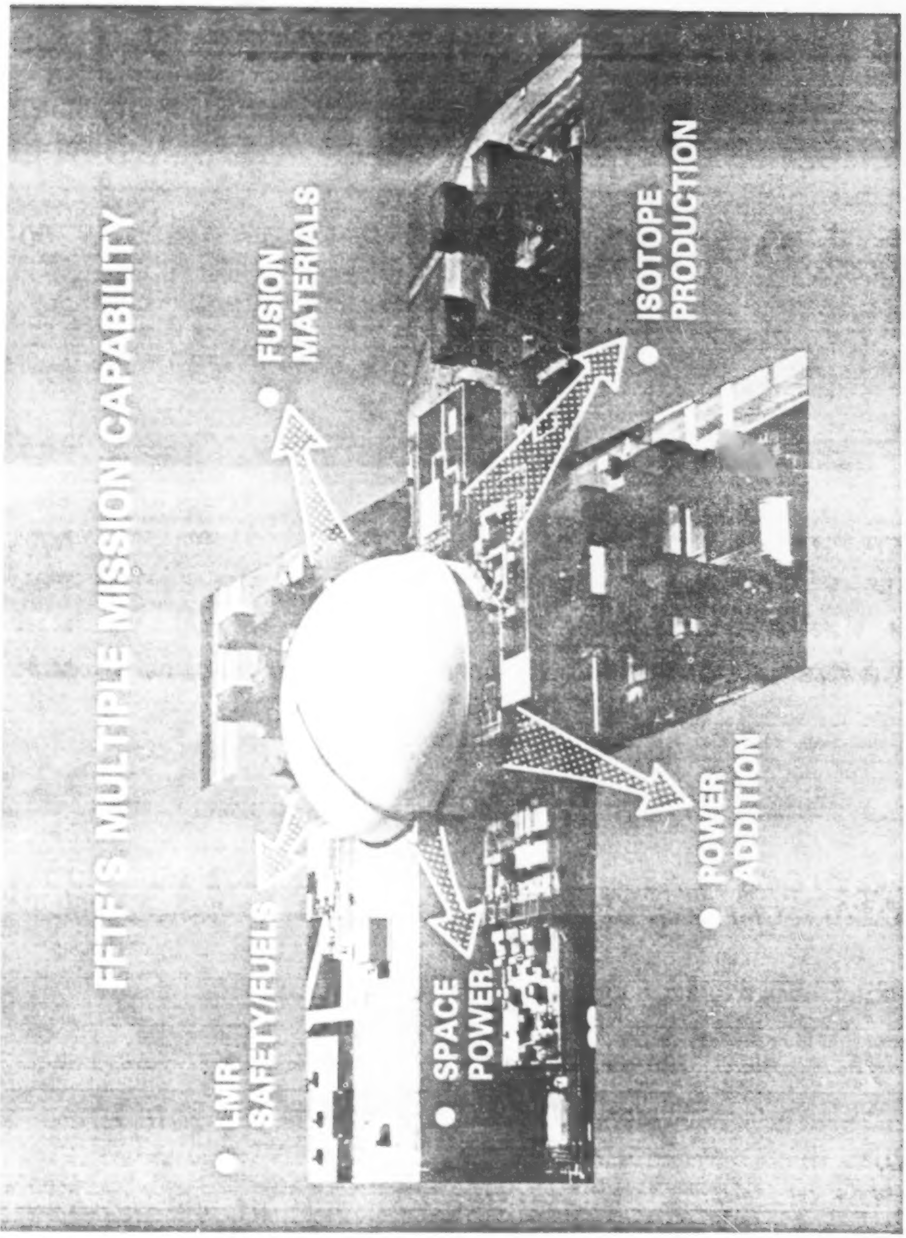


38711-108.N-2M

CONTROLLING PERSONNEL RADIATION EXPOSURE



38803-068.7M



FFTF'S MULTIPLE MISSION CAPABILITY

- LMR SAFETY/FUELS
- SPACE POWER
- FUSION MATERIALS
- ISOTOPE PRODUCTION
- POWER ADDITION

MULTIPLE MISSION CONCEPT
POTENTIAL MISSIONS FOR FFTF

- NUCLEAR ENERGY
  - LMR FUELS AND MATERIALS DEVELOPMENT
  - LMR PLANT EXPERIENCE
  - SPACE POWER FUELS AND MATERIALS TESTING

- ENERGY RESEARCH
  - FUSION MATERIALS TESTING
  - ISOTOPE PRODUCTION

- DEFENSE PRODUCTION
  - ^{238}Pu - THERMAL ISOTOPE POWER SOURCES
  - SPECIAL NUCLEAR MATERIALS PRODUCTION
  - TRITIUM TARGET TESTING
  - WEAPONS PLUTONIUM BURN (INVENTORY REDUCTION)

- RADIOACTIVE WASTE
  - WASTE BURN (CURE PROGRAM) TESTING

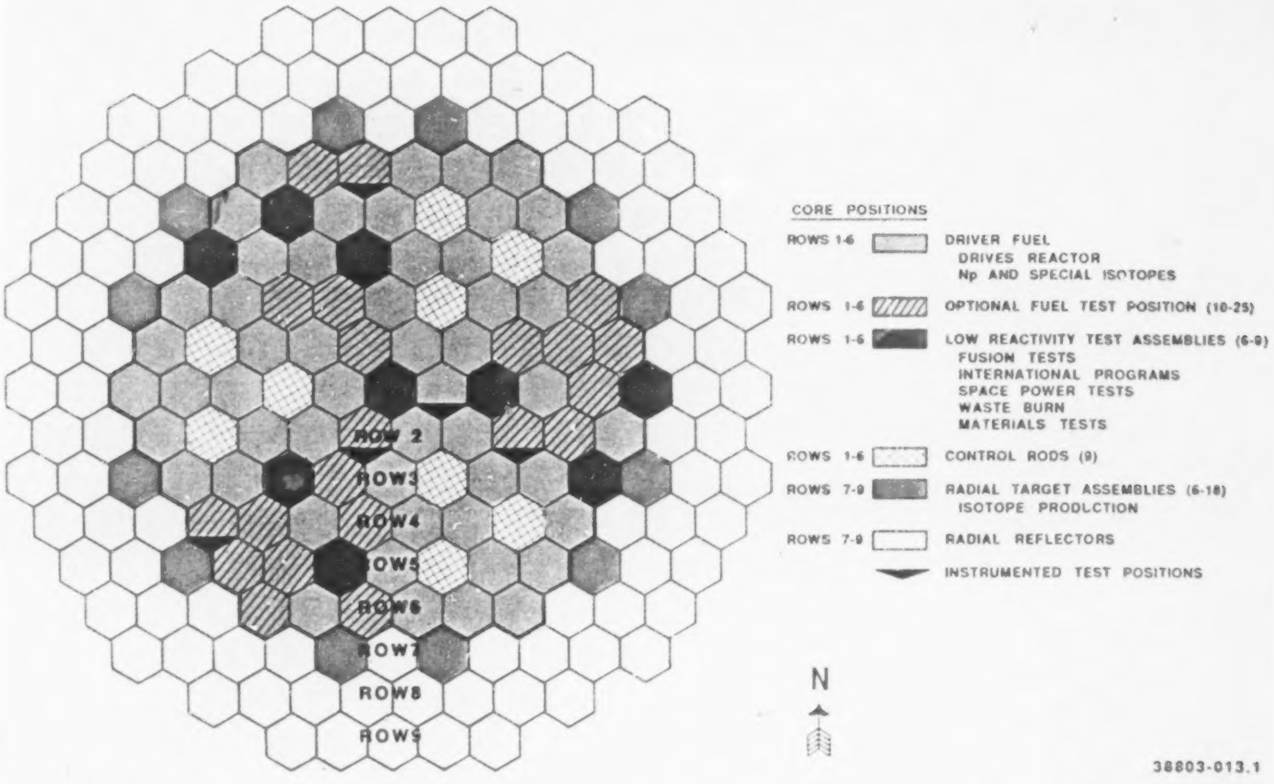
- FFTF POWER ADDITION

MULTIPLE MISSION CORE

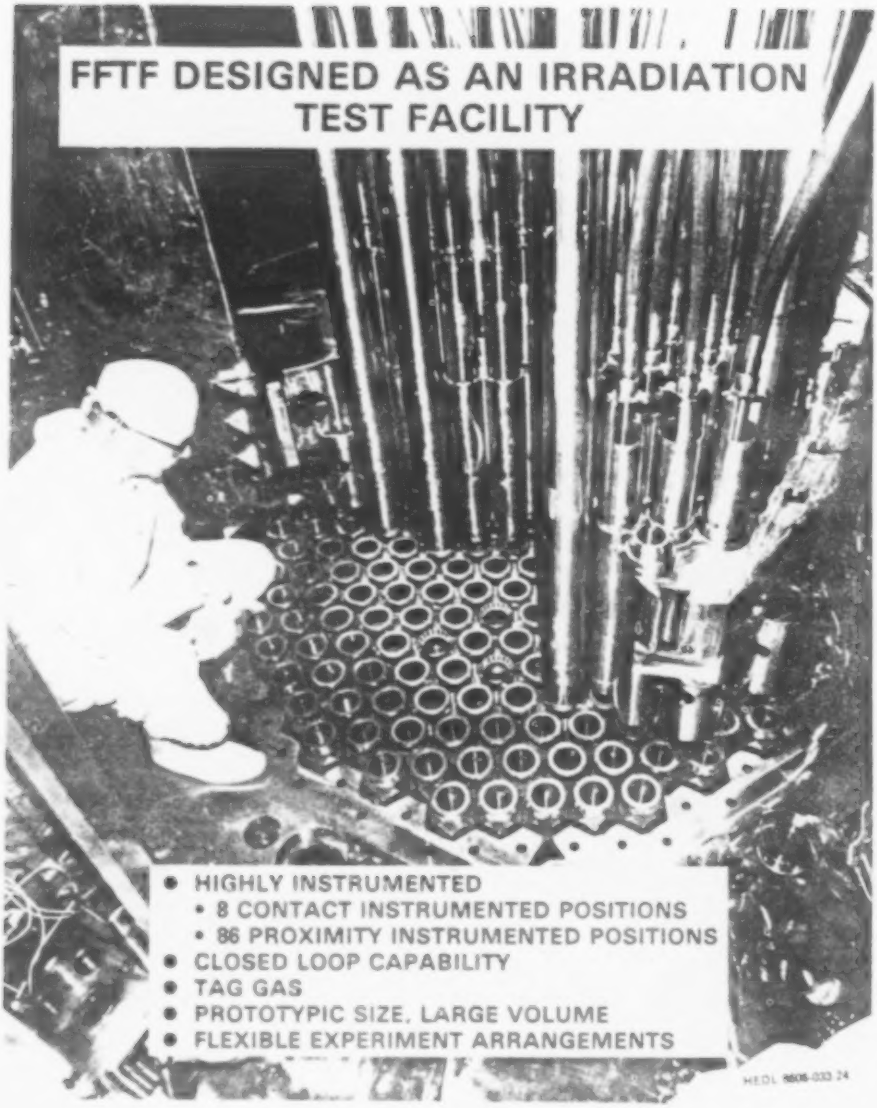
- DRIVER FUEL (50-60 ASSEMBLIES)
  - DRIVES REACTOR
  - GENERATES USEFUL ISOTOPES
- TEST FUEL (10-25 ASSEMBLIES)
  - DRIVES REACTOR
  - GENERATES TECHNOLOGY
- LOW REACTIVITY TESTS (6-9 POSITIONS)
  - TESTS
  - ISOTOPE IRRADIATIONS
- RADIAL TARGETS (6-18 POSITIONS)
  - ISOTOPE PRODUCTION

38803-068.21M

FFTF VERSATILITY OFFERS HIGH POTENTIAL FOR MULTIPLE MISSIONS


ROW 2
ROW3
ROW4
ROW5
ROW6
ROW7
ROW8
ROW9
CORE POSITIONS
ROWS 1-6 DRIVER FUEL
DRIVES REACTOR
Np AND SPECIAL ISOTOPES
ROWS 1-6 OPTIONAL FUEL TEST POSITION (10-25)
ROWS 1-6 LOW REACTIVITY TEST ASSEMBLIES (6-9)
FUSION TESTS
INTERNATIONAL PROGRAMS
SPACE POWER TESTS
WASTE BURN
MATERIALS TESTS
ROWS 1-6 CONTROL RODS (9)
ROWS 7-9 RADIAL TARGET ASSEMBLIES (6-18)
ISOTOPE PRODUCTION
ROWS 7-9 RADIAL REFLECTORS
INSTRUMENTED TEST POSITIONS
N
38803-013.1

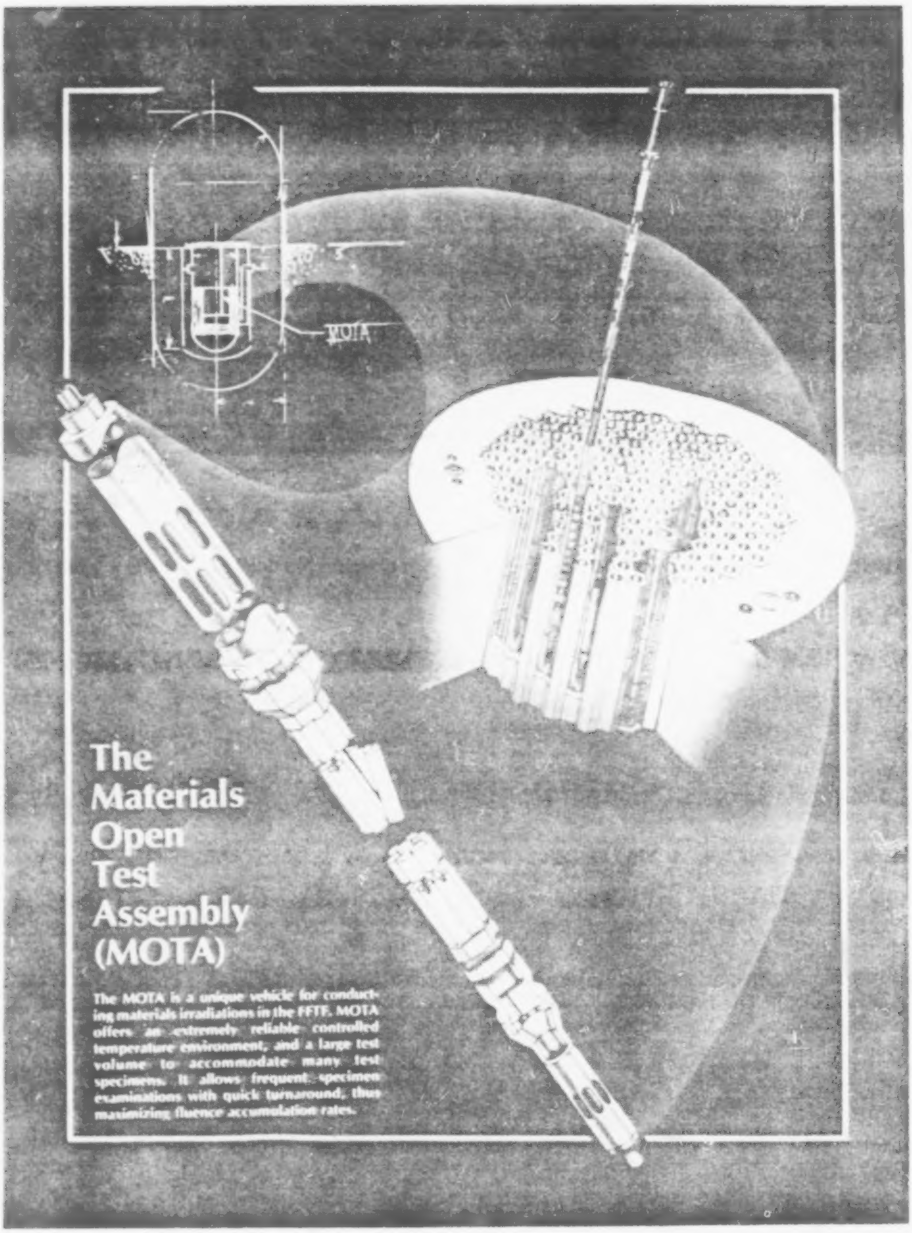
FFTF CORE MAP



FFTF DESIGNED AS AN IRRADIATION TEST FACILITY

- HIGHLY INSTRUMENTED
  - 8 CONTACT INSTRUMENTED POSITIONS
  - 86 PROXIMITY INSTRUMENTED POSITIONS
- CLOSED LOOP CAPABILITY
- TAG GAS
- PROTOTYPIC SIZE, LARGE VOLUME
- FLEXIBLE EXPERIMENT ARRANGEMENTS

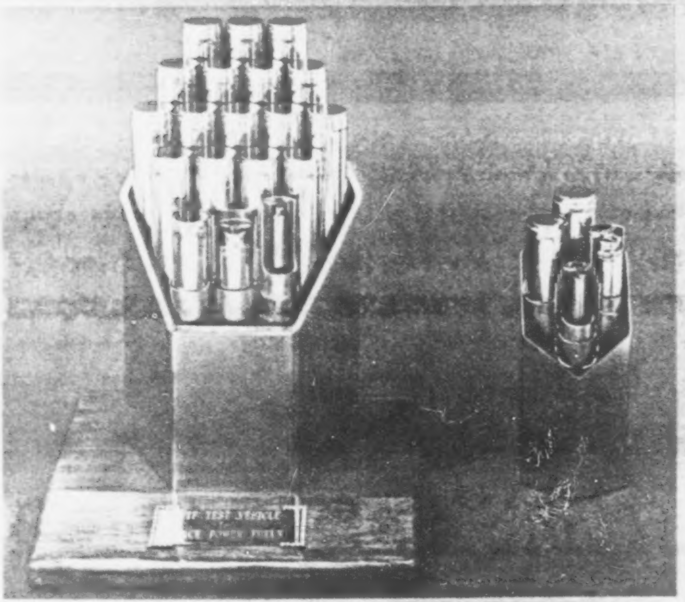
HEDL 8606-033.24



The Materials Open Test Assembly (MOTA)

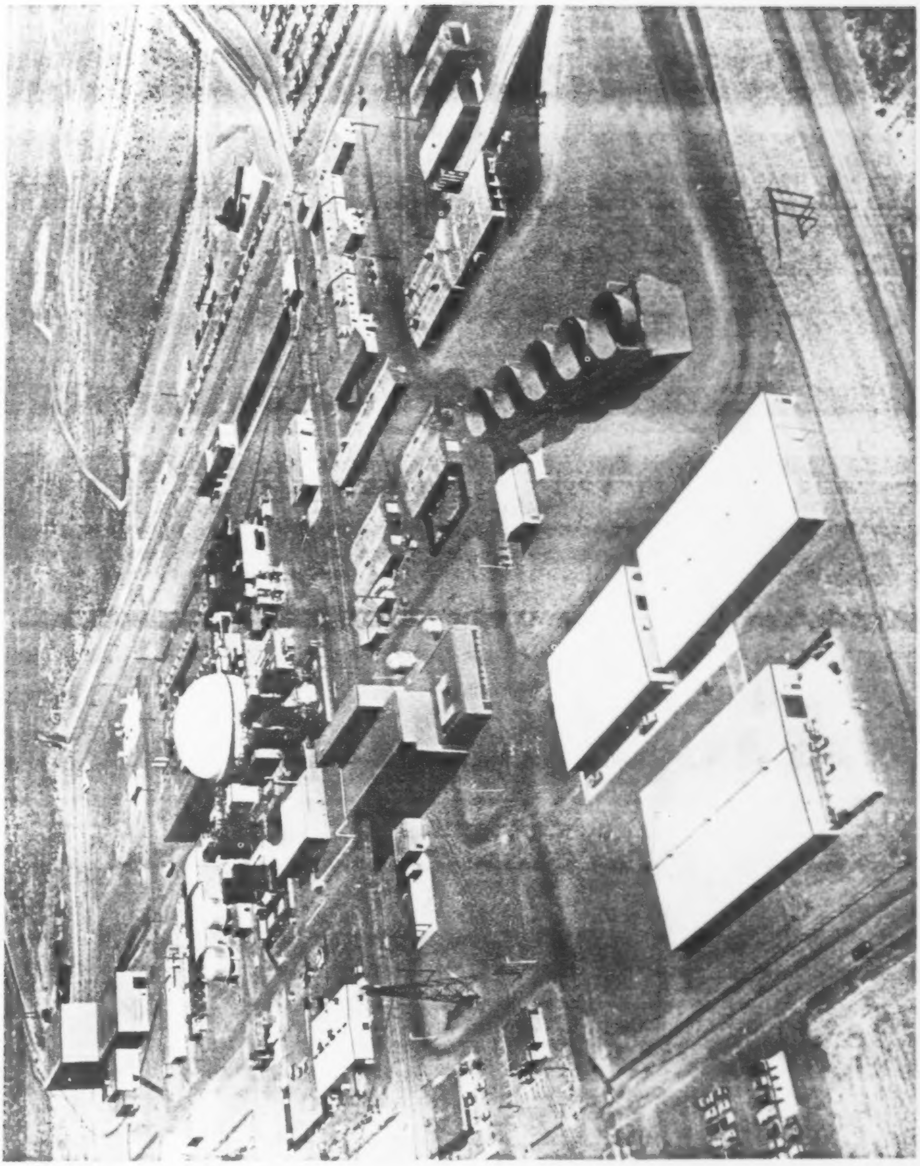
The MOTA is a unique vehicle for conducting materials irradiations in the FFTF. MOTA offers an extremely reliable controlled temperature environment, and a large test volume to accommodate many test specimens. It allows frequent specimen examinations with quick turnaround, thus maximizing fluence accumulation rates.

SP-100 IRRADIATION TESTING HARDWARE



FFTF EBR-II

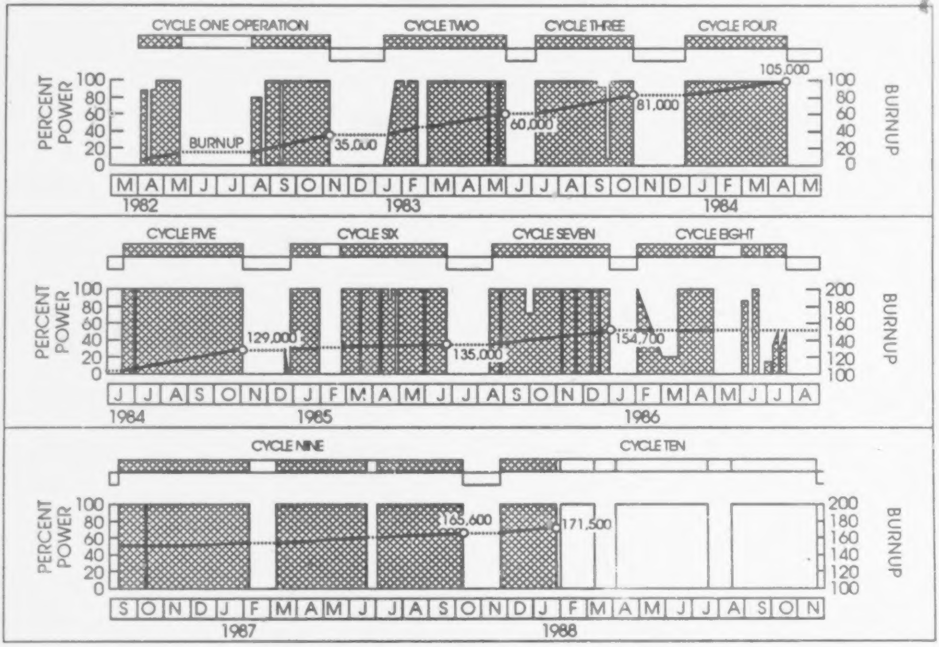
HEDL [illegible]



FFTF WITH PROPOSED POWER ADDITION IN FOREGROUND.

FFTF

OPERATING HISTOGRAM



OPERATING STATISTICS

	CYCLE 1	CYCLE 2	CYCLE 3	CYCLE 4	CYCLE 5	CYCLE 6	CYCLE 7	CYCLE 8	CYCLE 9	CYCLE 10 (1/31/88)
EFPD FOR CYCLE:	101.5	100.5	101.5	109.5	122.7	134.0	122.8	63.0	341.8	66.3
TOTAL PLANT EFPD AT END OF CYCLE:	134.3	234.8	336.3	445.8	568.5	702.5	825.3	888.3	1230.1	1296.4
CYCLE CAPACITY FACTOR (%):	50.3	83.1	93.5	99.5	93.5	74.9	90.3	38.9	86.6	89.4
AVAILABILITY FACTOR (%):	53.0	90.6	99.0	100.0	94.6	78.5	94.6	57.9	89.6	92.5
NUMBER OF EXPERIMENTS:	61	64	57	51	51	41	31	19	44	42
MAXIMUM FUEL BURNUP AT END OF CYCLE (MWd/MT):	35,000	60,000	81,000	105,000	129,000	135,000	154,700	154,700	165,600	171,500

ANNUAL OPERATIONAL PERFORMANCE

	1982 *	1983	1984	1985	1986	1987 (1/31/88)
CAPACITY FACTOR (%):	40.5	56.9	66.4	71.0	46.2	76.5
AVAILABILITY FACTOR (%):	42.8	61.1	67.6	73.0	56.8	78.7
OPERATIONAL EFFICIENCY FACTOR (%):	63.5	97.6	92.6	98.0	98.1	100.0

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* Reporting began at start of Cycle 1 on April 16, 1982

Attachment 4

FUEL AND ABSORBER PERFORMANCE

The FFTF's fuel and absorbers, including test components, continued to perform flawlessly during 1987. The performance of one and two year lifetime fuel systems continued to be limited only by swelling of the stainless steel components used in their fabrication. Fuel and absorber components are routinely irradiated to 150 percent of their design goal lifetimes.

Even more importantly, demonstration of the merits of using the non-swelling stainless alloy HT9 for long lifetime components continues to be highly successful. At this time, the Core Demonstration Experiment (10 fuel and 6 blanket assemblies) has achieved one-half of its goal exposure of three years (900 Effective Full Power Days, EFPD) and comparable lead tests have achieved up to 75 percent of the exposure goal. Examination of a companion test at two-thirds goal exposure confirmed the non-swelling character of the newly-developed HT9 steel. Collectively this information supports high expectations that an LMR fuel system having a three to four year lifetime capability will be fully demonstrated by 1990. Achievement of this goal will reduce future fuel cycle costs for an LMR by a factor of three compared to that for the initial LMR fuel designs. It is both exciting and gratifying that the next two years will witness this major breakthrough in oxide fuel technology.

Development of uranium-zirconium (U-Zr) metal fuel for FFTF is a relatively new initiative (1986). The major incentive is to reduce FFTF fuel costs using a combination of ANL and WHC facilitates to fabricate the fuel. Demonstration of the performance capability of prototypic full-length HT9 clad fuel pins was initiated in 1987 and early-in-life performance results (200 EFPD) are expected during 1988. Results will be used to confirm performance projections which are based currently upon the observed performance of short fuel pins irradiated in EBR-II. At the same time these results will benefit and support ANL's Integral Fast Reactor (IFR) metal fuel development program. The first two of an additional 17 prototype U-Zr metal FFTF assemblies will start irradiation toward a goal burnup of 140

MWd/kgM (900 EFPD) this year. These prototype tests include nominal and peak power conditions exposed for varying lifetimes in FFTF. The lead IFR metal fuel test (D9 alloy components) in FFTF has achieved over two-thirds of its goal exposure of 600 EFPD. Irradiation will be completed in 1988.

Irradiation of three prototype assemblies for Japan's MONJU Reactor (two fuel and one blanket) was initiated in 1987. These tests, which utilize both cladding and duct components provided by Japan (PNC), are being irradiated in a fully prototypic reactor environment to a goal exposure of 600 EFPD. Irradiation will be completed in 1990.

The FFTF continues to be the world's premier test reactor for development of LMR core components. The above tests benefit substantially from the prototypic environment and full proximity instrumentation. The validity of FFTF test data is without equal throughout the world.

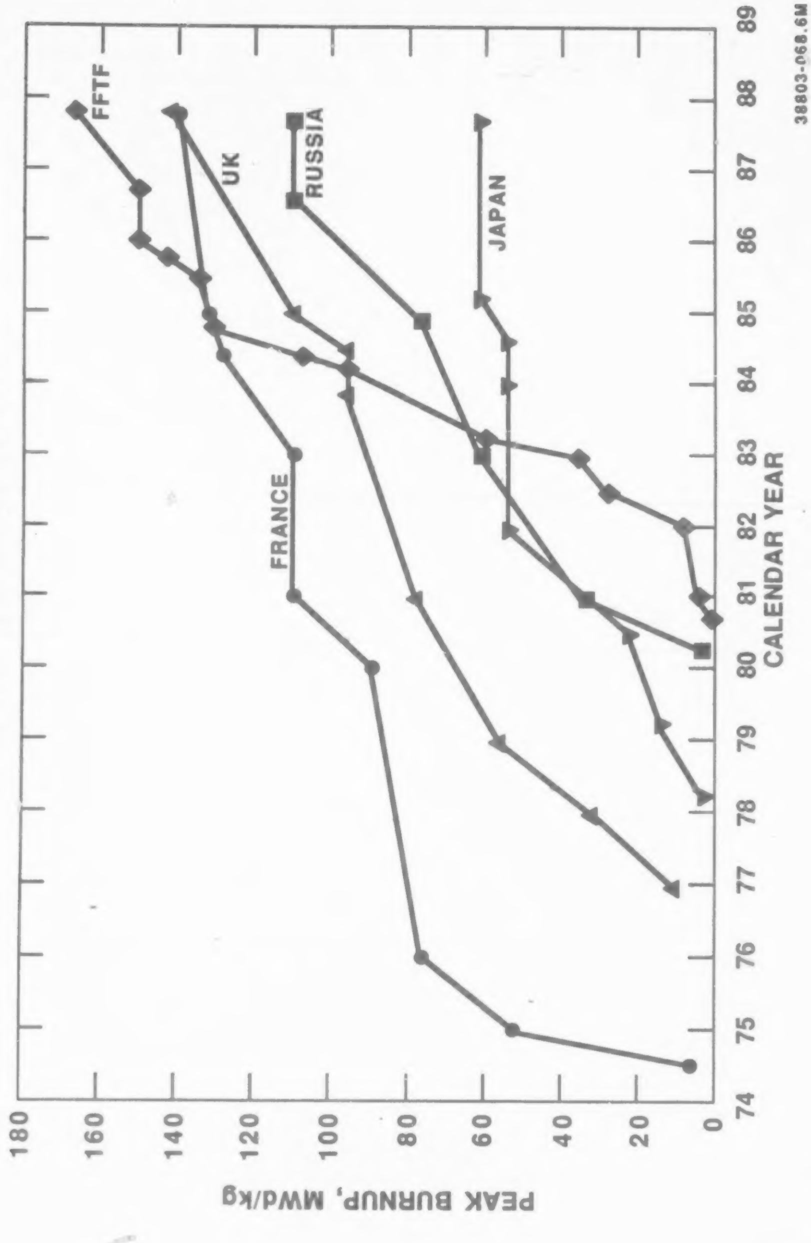
CORE DEMONSTRATION EXPERIMENT

FEATURES:

- PARTIAL CORE LOADING OF HT9 CLAD, MIXED-U-Pu OXIDE FUEL AND U OXIDE BLANKETS IN FFTF
- 900 TO 1200 EFPD RESIDENCE TIME — (160-220 MWd/kgM)
- FULLY PROTOTYPIC OF COMMERCIAL PLANT: CONFIGURATION, SIZE, AND MATERIALS
- IRRADIATION BEGAN IN SEPTEMBER 1986, 420 DAYS OF IRRADIATION COMPLETED
- GOAL EXPOSURE TO BE REACHED IN 1989
- LEAD TEST REACHED PEAK BURNUP OF 130 MWd/kgM

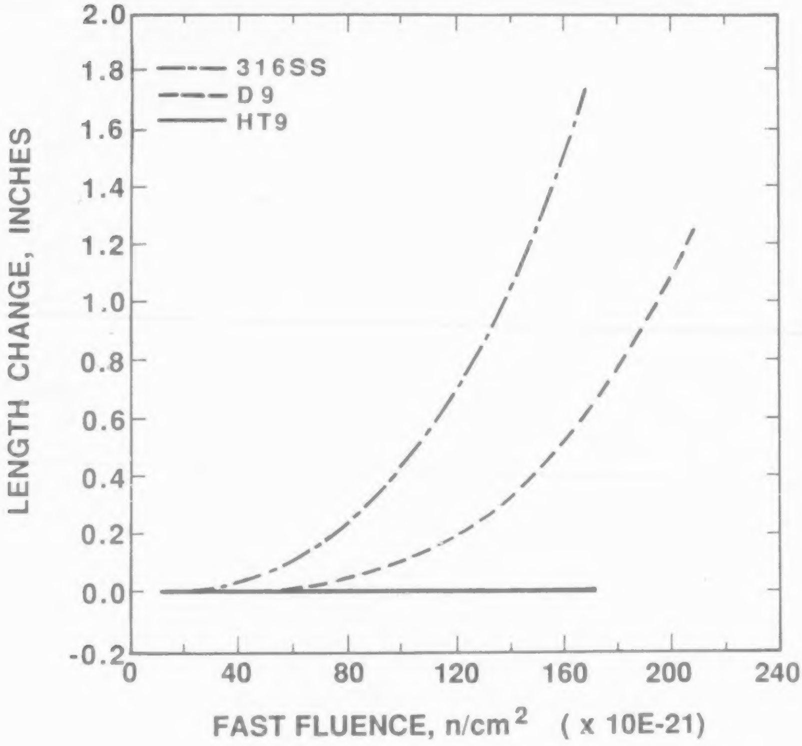
HEDL 8703-052.3

BURNUP ACHIEVEMENTS IN LIQUID METAL REACTORS



LEAD TESTS SHOW FERRITIC/MARTENSITIC ALLOY HT9 SOLVES SWELLING IN FAST REACTORS

316, D9, AND HT9 PIN LENGTH CHANGE



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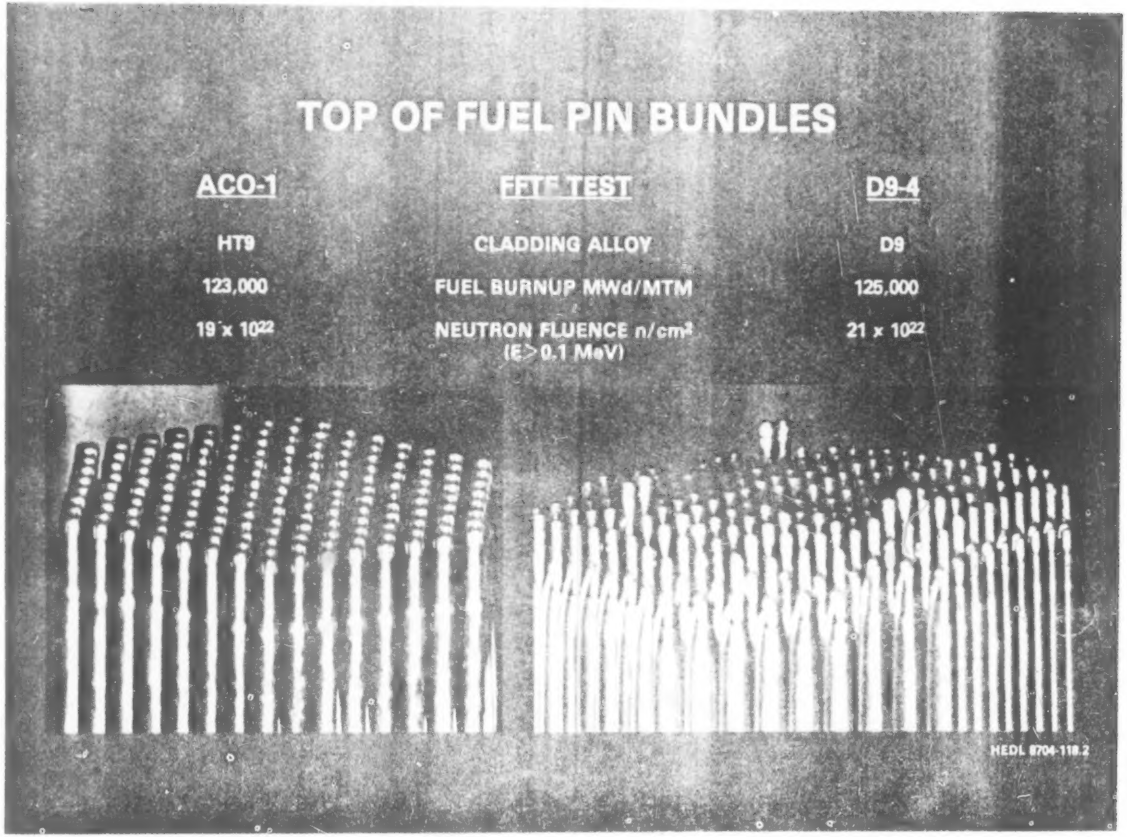


TOP OF FUEL PIN BUNDLES

ACO-1	FFTF TEST	D9-4
HT9	CLADDING ALLOY	D9
123,000	FUEL BURNUP MWd/MTM	125,000
19×10^{22}	NEUTRON FLUENCE n/cm^2 (E > 0.1 MeV)	21×10^{22}

NO LENGTH CHANGE IN NON-SWELLING FUEL PINS AFTER IRRADIATION.

VARIABLE LENGTH CHANGES IN IMPROVED ALLOY FUEL PINS AFTER IRRADIATION.

Attachment 5

FFTF FUEL SUPPLY

The FFTF began operation in 1980 and continues to operate using commercially fabricated mixed-oxide (plutonium-uranium oxide) fuel pins. Both of the commercial fabricators have ceased operations insofar as LMR fuels are concerned. The supply of commercially-procured mixed-oxide fuel will be expended during FY1991. Before that time a new fully qualified, high quality fuel source must be established. Current plans are to work with ANL to jointly develop a capability to fuel the FFTF with metal fuel.

308 BUILDING OPERATIONS

During the past twenty years the 308 Building in the 300 Area at Hanford has been the focal point of LMR fuel development and supply for the FFTF. Since 1970 the following major fuel supply functions have been performed:

- Some 10,650 test fuel pins have been produced from mixed-oxide powders for irradiation assemblies.
- Approximately 78,700 driver fuel pins from commercial fuel suppliers were received, inspected, and certified for the FFTF.
- 389 driver fuel assemblies for the FFTF were assembled from the commercially supplied fuel pins.

The process development required to produce the of mixed-oxide fuel test pins was also conducted in the 308 Building. In addition, development programs have been ongoing from 1968 related to joining techniques, assembly operations, and the fabrication of various test assemblies including the 40-foot long fueled open test assemblies. The development of pulsed magnetic welding is especially noteworthy since it provides a method for joining metals not generally amenable to conventional fusion-type welding and has a high potential for use in remote operations.

Continuing activity in the 308 Building includes the following:

- Fabrication of fuel test assemblies for the FFTF.

- Fabrication of test assemblies for the Space Power Program for irradiation in the FFTF.

- Fabrication of FFTF tests for the Japanese PNC as part of the International Collaboration Program.

- Development of a metal fuel fabrication system to supply lead test assemblies and driver fuel for the FFTF.

Current plans call for discontinuing all 308 Building operations during FY1989.

FUEL ASSEMBLY AREA OPERATIONS

To accommodate the transition from a mixed uranium/plutonium ceramic to a uranium/zirconium metal fuel core in the FFTF, a metal fuel process line is being established at WHC to supply the new fuel assemblies. After the line is developed and tested in the 308 Building, several prototypic metal fuel assemblies will be fabricated. The line will then be relocated to the Fuels and Material Examination Facility (FMEF), on the Hanford site, where it will become fully operational in 1989. In addition, another smaller test fuel fabrication line will be established to develop and produce fuel for both national and international LMR irradiation test programs. Both of these fuel process lines will be located in the Fuel Assembly Area, a self-contained annex of the FMEF.

FUELS AND MATERIALS EXAMINATION FACILITY

The FMEF is a recently constructed nuclear materials processing facility that meets all current safety and security criteria. The building is designed to contain radioactive material in the event of earthquake or tornado and has security and materials accountability systems that meet all requirements for processing and storing large quantities of special nuclear material. The main process building is composed of six operating floors surrounding a central core of three large, heavily shielded, remotely operated process cells. A group of 13 smaller process cells are located on the lowest level of the FMEF.

Construction was completed in 1984. All original FMEF missions for evaluation of irradiated components from breeder reactors have been cancelled or deferred. Nuclear materials have not yet been introduced into the facility.

The facility is ideally suited for programs that require remote operation in a fully hardened structure. Such programs include:

- Clean Use of Reactor Energy (CURE).
- Radioisotope Power Systems for space and terrestrial applications.
- Isotope processing.
- Weapons material recycle.
- Defense materials fabrication.

The Secure Automated Fabrication (SAF) Line is located on the upper level of the FMEF. The SAF Line is an oxide nuclear fuel production line capable of throughputs of up to 40 tons of uranium oxide per year and is the only oxide fuel fabrication capability in the country for plutonium or for uranium enriched greater than ten percent ^{235}U. SAF is well suited for large-scale weapons-burn application and for fuel fabrication for a light water defense production reactor.

The small process cells on the lowest level of the FMEF have been selected as the area in which a Radioisotope Power Systems Facility will be installed. This facility will assemble and test general purpose heat source modules containing ^{238}Pu pellets. These modules will be combined into larger assemblies that will be power sources for space and terrestrial applications.

Approximately 60 percent of the FMEF process area is occupied by the SAF Line, the Radioisotope Power Systems Facility, and the building services. The remaining area (about 60,000 sq. ft.) is available for one or more of the programs listed above.

OVERALL DIRECTION OF FFTF FUEL SUPPLY

- ASSURE FFTF FUEL SUPPLY
- CONVERSION TO METAL FUEL
- EFFICIENT USE OF EXISTING OXIDE FUEL
- SUPPORT INTERNATIONAL INITIATIVES
- FUEL TEST FABRICATION
- MOVE 308 ACTIVITIES TO THE FMEF ANNEX
- MAINTAIN SAF IN LAY UP CONDITION
- ACQUIRE AND ASSEMBLE NON-FUEL COMPONENTS AS NEEDED
- DEVELOP ALTERNATE FMEF MISSIONS

38710-163.D-2M

FFTF FUEL SUPPLY
BACKGROUND AND REQUIREMENT

- OXIDE TEST FUEL OPERATIONS IN 308 BUILDING TERMINATED. TEST PIN LINE (TPL) ENCLOSURES PLACED IN LAY UP.
- FUEL FABRICATION CAPABILITY TO MOVE TO FAA
- HANFORD SITE NO LONGER HAS CAPABILITY TO FABRICATE ENRICHED URANIUM OR MIXED OXIDE FUELS
- VITAL TO MAINTAINING CAPABILITY FOR FABRICATION OF CERAMIC TEST FUELS
- ENHANCES CONTINUED OPERATION OF FFTF THROUGH NATIONAL AND INTERNATIONAL LMR TEST PROGRAM PARTICIPATION

38801-127.K-26

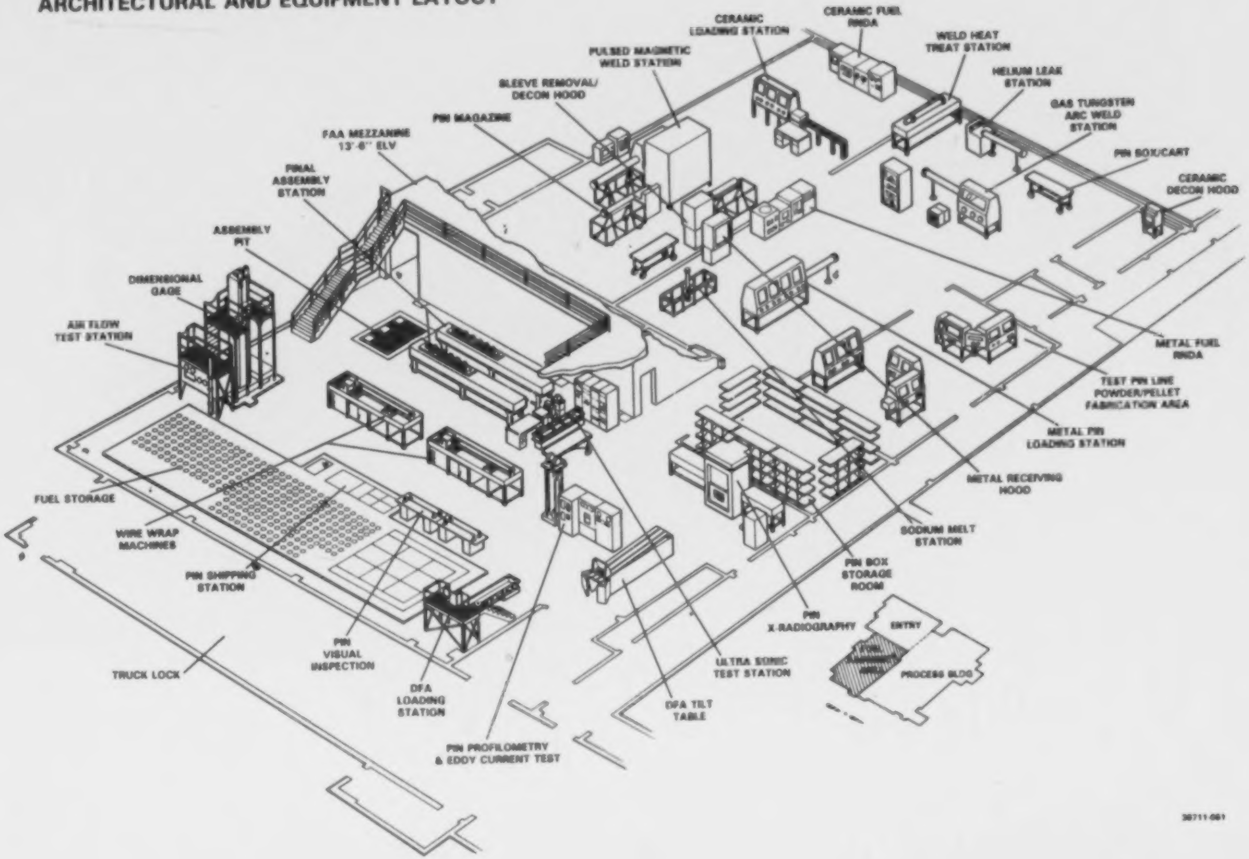
FUEL ASSEMBLY AREA PROCESS SCOPE

- FUEL SHIPPING, RECEIVING, STORAGE
- FUEL PIN FABRICATION
- FUEL ASSEMBLY FABRICATION
- TEST FUEL FABRICATION

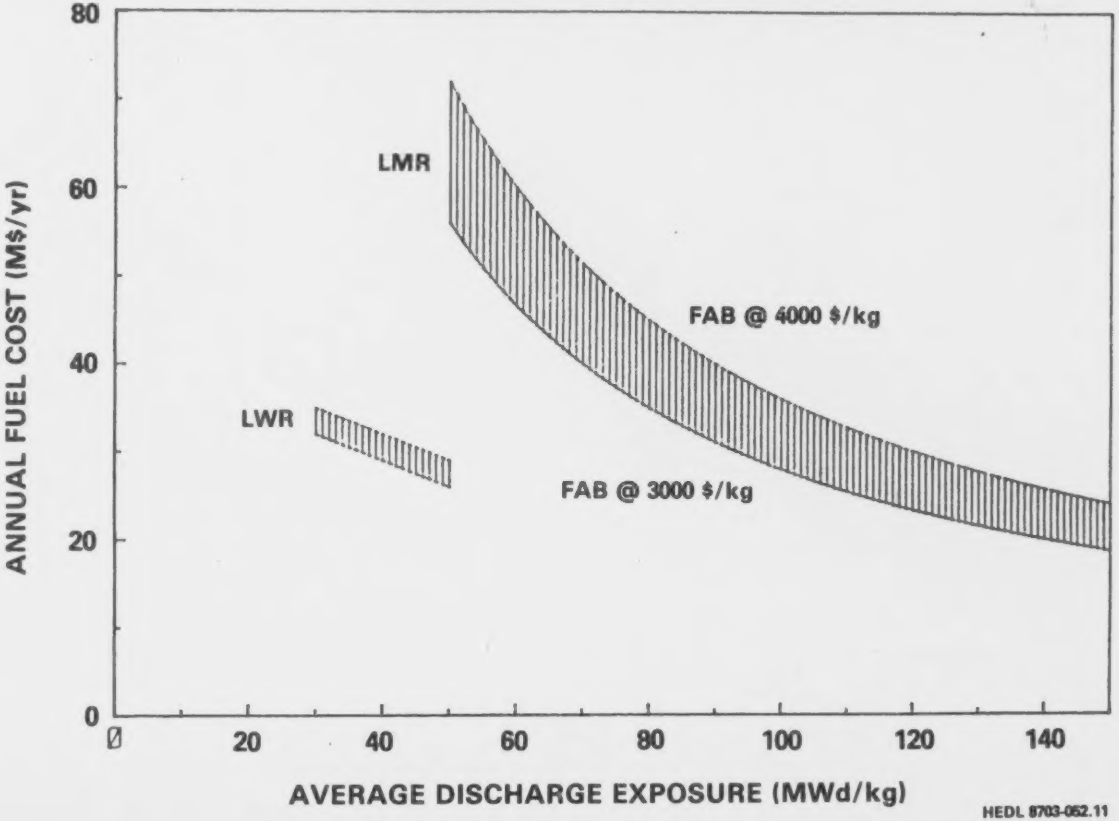
38803-069.20M

FUEL ASSEMBLY AREA

ARCHITECTURAL AND EQUIPMENT LAYOUT


CERAMIC LOADING STATION
CERAMIC FUEL RMDA
WELD HEAT TREAT STATION
HELIUM LEAK STATION
GAS TUNGSTEN ARC WELD STATION
PIN BOX/CART
CERAMIC DECON HOOD
PULSED MAGNETIC WELD STATION
SLEEVE REMOVAL/ DECON HOOD
PIN MAGAZINE
FAA MEZZANINE 13'-6" ELV
FINAL ASSEMBLY STATION
ASSEMBLY PIT
DIMENSIONAL GAGE
AIR FLOW TEST STATION
FUEL STORAGE
WIRE WRAP MACHINES
PIN SHIPPING STATION
TRUCK LOCK
PIN VISUAL INSPECTION
DFA LOADING STATION
PIN PROFILOMETRY & EDDY CURRENT TEST
DFA TILT TABLE
ULTRA SONIC TEST STATION
PIN X-RADIOGRAPHY
ENTRY
PROCESS BLDG
PIN BOX STORAGE ROOM
SODIUM MELT STATION
METAL RECEIVING HOOD
METAL PIN LOADING STATION
TEST PIN LINE POWDER/PELLET FABRICATION AREA
METAL FUEL RMDA
38711-081

INCREASING BURNUP SAVES MILLIONS OF DOLLARS EVERY YEAR



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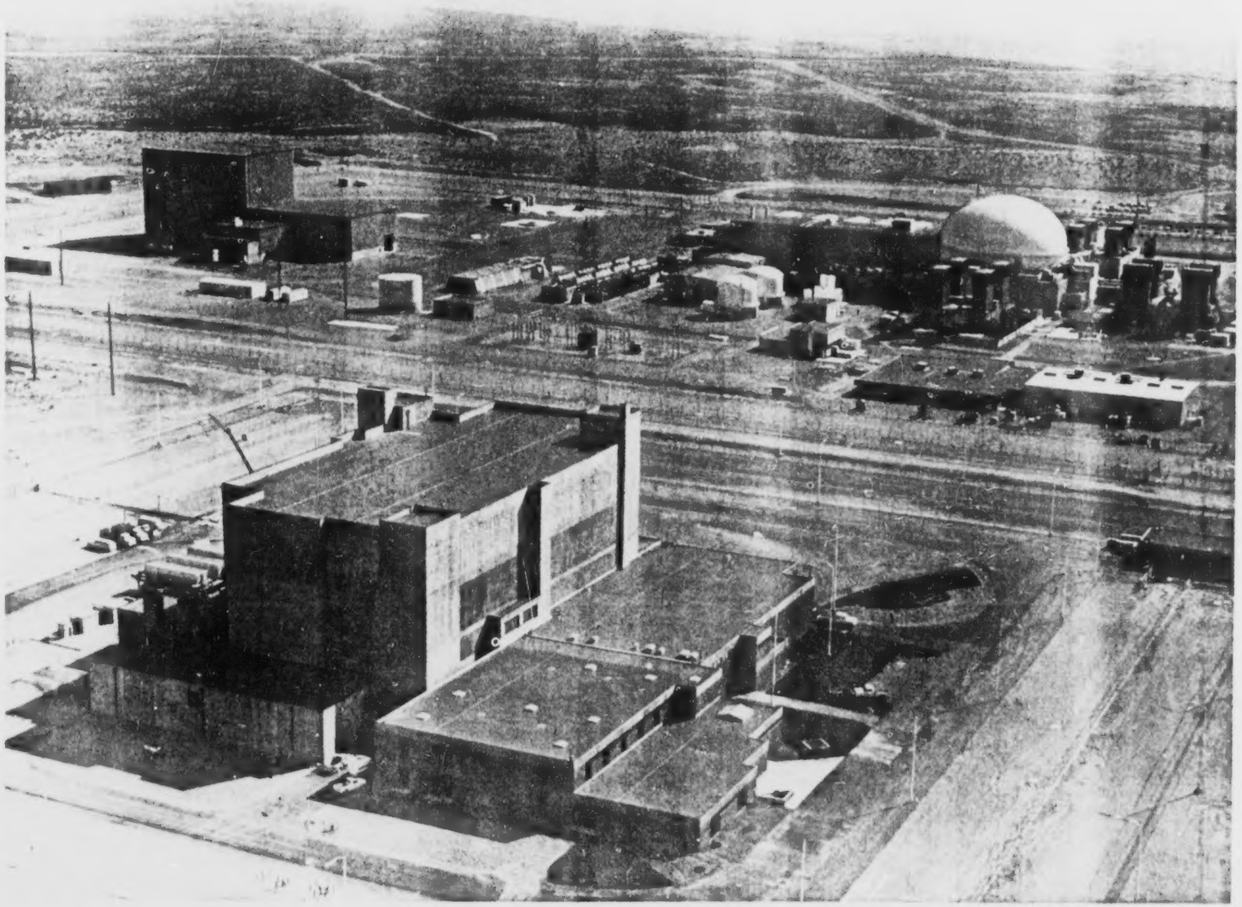


Attachment 6

SPACE NUCLEAR POWER

Since 1983, space nuclear power has been an increasingly important program at Westinghouse Hanford Company (WHC) and has evolved into a major, comprehensive mission. The flagship of the program, the SP-100 Ground Engineering System (GES) Test Facility, has gained momentum in preparing to test the SP-100 prototype nuclear reactor, flight shield, and control system. Irradiation testing activities which started in 1983 to support the SP-100 concept selection have expanded as WHC has been selected as the lead irradiation testing laboratory for multimegawatt and thermionic fuel element development as well as for SP-100. Recently, the Department of Energy selected the Fuels and Materials Examination Facility at Hanford as the preferred site for the Radioisotope Power Systems Facility.

Design was completed for the SP-100 GES Test Site in October, 1987. The reactor containment building and the adjacent service building were cleared of obstructing equipment from the earlier reactor test so that the facility is now ready for construction modifications. Seventy-five percent of the refurbishment activities were completed for surplus liquid metal equipment which was transferred to SP-100 from the Fast Flux Test Facility (FFTF). The current focus is on definitive design and on preparation of the Preliminary Safety Analysis Report. Long lead procurement activities will be initiated in FY 1988, and the new construction activities will start in FY 1989. Through detailed planning among WHC, GE, the SP-100 Project Office, and DOE, the impact of the shortfall in the FY 1988 SP-100 funding was minimized on the Test Site so that the planned date for reactor criticality was shifted only four months, to January 1992. Costs for FY 1988 are estimated to be $11M. The schedule is based on cost estimates of $25M and $17M for FY 1989 and FY 1990, respectively.

We have been involved in technology development programs for space nuclear power since 1983. In this area, the prime responsibility of WHC is to design, fabricate, conduct, and examine irradiation tests necessary to validate performance of reactor fuels and materials. This year, three new tests were fabricated and placed under irradiation in the FFTF. Two of the tests, which are being conducted in support of SP-100, represent a considerable extension of testing capability. Both tests, one which contains 38 fuel pins and one with

398 material samples, are operating at 2,250°F consistent with the high temperatures required to maximize the efficiency and minimize the mass of thermoelectric space power systems. The third test initiated this year is the second in a series of high temperature tests which support the Multimegawatt Thermionics Program. Two irradiation tests conducted last year are undergoing detailed examination. One of these tests is providing key data to allow the Multimegawatt Thermionics Program to select materials which will retain their electrical insulating properties even though they operate within the reactor core. The other test is providing confirmation of the performance of the SP-100 fuel system at approximately two-thirds the required burnup.

The Radioisotope Power Systems Facility (RPSF) will support assembly, testing, and storage of power sources for NASA deep space missions, Department of Defense terrestrial applications, and Strategic Defense Initiative satellites. These power sources will range from 1 watt to 10 kilowatts electrical power and will use ^{238}Pu for their heat source. The Conceptual Design Report and National Environmental Policy Act documentation for the RPSF will be submitted to the Department of Energy in March. Near-term activities will focus on completing preliminary design by October 1988. Construction is scheduled to begin in FY 1989 and assembly operations in FY 1991.

The Fuels and Materials Examination Facility has the potential to produce ^{238}Pu fuel forms used in the radioisotope power sources. Hot cells adjacent to the power source assembly operations are available to process plutonium dioxide powders obtained from chemical separation operations into fuel pellets and encapsulate them. The Department of Energy has requested a preconceptual design study for ^{238}Pu fuel pellet fabrication and encapsulation operations in these hot cells. Consolidation of ^{238}Pu operations would save assembly, shipping, and security costs.

SP-100 Ground Engineering System Test Site

Objectives and Scope

The objective of the SP-100 Nuclear Assembly Test is to demonstrate performance of a full-scale prototypic reactor, flight shield, and control system for a 100 KWe space power system. The GE reactor design is modular such that the same technology is applicable for space power systems in the range 10 KWe to 1 MWe. The Nuclear Assembly Test program is a joint endeavor of GE and WHC under the auspices of the SP-100 Project Office and the Department of Energy. General Electric (GE), the System Developer, will design the SP-100 space power system, fabricate the prototype reactor system, and define the test program. Westinghouse Hanford Company, the Site Operator, will design the test facility and site systems to meet the program requirements, modify the existing facility, construct the necessary new systems, and perform the test program. The major support systems provided at the Test Site include a large vacuum system to simulate the space environment, heat rejection systems to dispose of the reactor heat, and the facility control system. Kaiser Engineers Hanford (KEH), the on-site Hanford architect/engineer and construction contractor, will share the facility design responsibilities with WHC and will manage all site construction activities. In addition, Los Alamos National Laboratory (LANL) will provide the reactor fuel for the test program.

Accomplishments

During the past year, we have:

- Completed preliminary design of the Test Site (Figure 1).

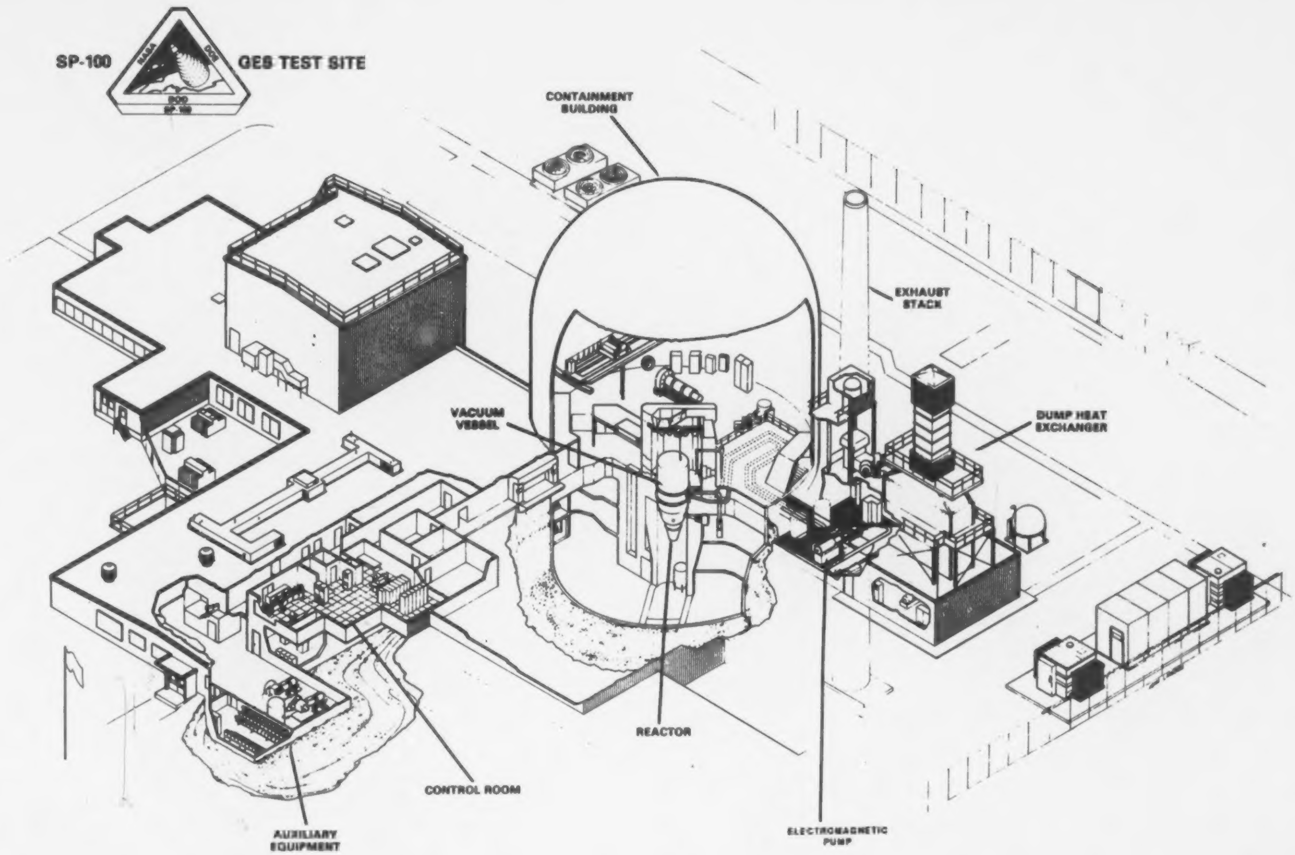
- Refurbished 75% of the surplus liquid metal equipment being transferred from FFTF to SP-100. This includes electromagnetic pumps and controls, flow meters, expansion tanks, valves, and motor-generator sets.

- Completed removal of obstructing equipment from the containment and service buildings. This activity involving 40,000 manhours of construction labor and lifts up to 37 tons was successfully performed with no accidents and no radioactive contamination of personnel. Figure 2 shows removal of the steam generator from the earlier reactor test.

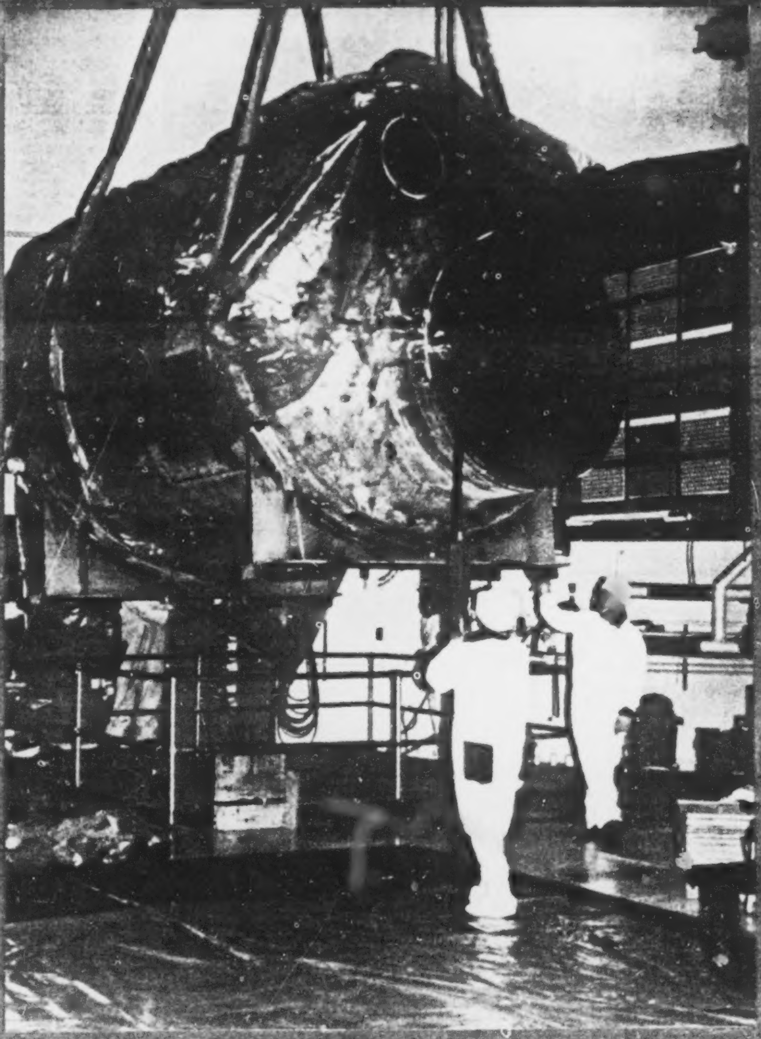
- Developed a close working relationship with GE, the System Developer, including an integrated work schedule and clearly defined interface controls.

Plans

Current activities are focusing on definitive design with preparation of construction specifications and equipment procurement specifications and on preparation of the Preliminary Safety Analysis Report. As shown on the summary schedule in Figure 3, construction modifications are planned to start in summer 1989, to meet a reactor criticality schedule of January 1992.


SP-100
GES TEST SITE
CONTAINMENT BUILDING
EXHAUST STACK
DUMP HEAT EXCHANGER
VACUUM VESSEL
REACTOR
CONTROL ROOM
AUXILIARY EQUIPMENT
ELECTROMAGNETIC PUMP

REMOVAL OF PRTR STEAM GENERATOR



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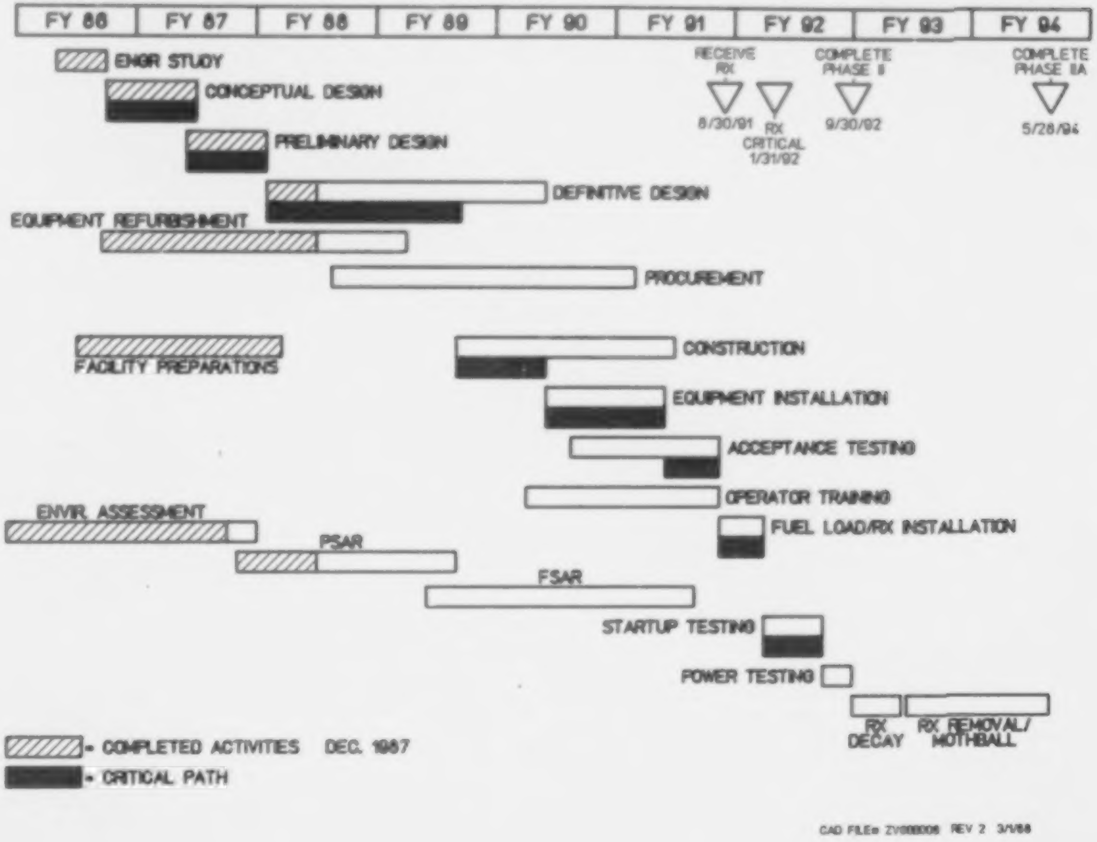
SP–100 TEST SITE SCHEDULE



Space Nuclear Power Technology

Objective and Scope

The objectives of technology development at WHC are to provide data necessary to select materials and verify component designs for the stringent requirements of space nuclear reactor application. Westinghouse Hanford Company performs the test design to assure the test will meet requirements, fabricates the test to existing quality assurance standards, conducts the test, and is responsible for performing the post-test examinations and analyses. Test requirements are provided by an industrial contractor. Data from test examinations are provided expeditiously to the contractor for incorporation into the design. The working relationship between WHC, contractor, and Program Office is excellent, making effective use of available resources.

Accomplishments

- 5 atom % (85% of goal) burnup was achieved in the lead SP-100 fuel irradiation tests.
- Examination of irradiated fuel pins at 75% goal burnup provided verification of the fuel system selected for SP-100.
- Large scale (38 fuel pins) testing to obtain data for performance model development was initiated in FFTF.
- Instrumented and temperature-controlled materials test to allow design correlations for SP-100 materials performance was initiated in FFTF.
- Component tests irradiated in FFTF and temperature-controlled conditions provided the basis for insulator and cesium reservoir selection for the thermionics program.
- Fast reactor tests of thermionic fuel showed better than anticipated performance.

- Particle fuel and fuel elements for an advanced multimegawatt, burst power, gas-cooled reactor were procured from a commercial supplier.

These activities were performed in cooperation with Los Alamos, Sandia, Idaho, and Oak Ridge National Laboratories, and the respective Project Offices located at Jet Propulsion Laboratory, LANL, and INEL.

The fabrication of the irradiation tests occurs in the Hanford 300 Area (Figure 1). Experienced testing personnel work closely with test facilities (FFTF, EBR-II, ACRR, ATR) to assure the test is conducted to meet test objectives and will meet test site safety requirements. The tests are fabricated to the quality assurance requirements of NQA-1 and rigorously reviewed to assure all safety requirements are met. The tests are then inserted for irradiation (Figure 2) and their performance monitored by the test engineer. All the tests are designed and fabricated to meet system contractor-identified data requirements. Contractor representatives are continuously involved with the planning of post-test examinations conducted in the Hanford hot cells. These data are then used by the contractor to validate the design of the flight system.

Plans for the Remainder of FY 1988

- A test of SP-100 spring, bearing, neutron reflector, and special use metals will be initiated to allow materials to be selected in early 1989.

- The SP-100 pin engineering data test, FSP-1, will be removed from FFTF for an interim examination and new pins will be incorporated into the test for continual irradiation.

- Thermionics fuel elements will be nondestructively examined at approximately 50% of the goal burnup.

Plans Beyond 1988

- Three SP-100 fuel pin tests will be examined at goal burnup.

- A self-contained lithium loop test which provides fuel pin testing under prototypical conditions will be fabricated and placed under irradiation.
- Two irradiation tests to provide materials properties correlations will be examined.
- Three instrumented, temperature-controlled tests will provide support to the selection of thermionic materials and component designs.
- Four thermionic fuel screening tests will provide the basis for performance code development.
- A full scale, power-producing thermionic fuel element in FFTF will provide the first U.S. fast reactor confirmation of concept performance.

Space Reactor Material Samples and Components Being Loaded Into the FFTF Materials Open Test Assembly (MOTA).

SP-100 Fuels Test Being Loaded Into FFTF on February 3, 1988.

Radioisotope Power Systems Facility (RPSF)

Objectives and Scope

The objective of the Radioisotope Power Systems Facility (RPSF) program is to provide a facility for assembling and testing heat source assemblies for radioisotope power systems. The RPSF program is part of the Department of Energy's (DOE) Office of Special Applications (OSA) Radioisotope Power Systems Programs. These power systems will be used for NASA deep space missions, Department of Defense terrestrial and sea applications, and Strategic Defense Initiative boost surveillance and tracking satellites. The radioisotope plutonium-238 will be the heat source for these power systems. The RPSF (Figure 1) will be installed in Hanford's Fuels and Materials Examination Facility.

The major functions of this facility will be to assemble General Purpose Heat Sources (Figure 2), build these into heat source assemblies for a specific power system, and test assemblies for reliability and performance. As prime contractor, Westinghouse Hanford Company will be responsible for managing equipment design, procurement, installation, testing, and facility operation. Kaiser Engineers Hanford, the site architect/engineer and construction contractor, will design and manage facility modifications and construction activities.

Accomplishments

During the past year, we have:

- Submitted a cost proposal for the RPSF program
- Been chosen as prime contractor and operator for the facility with DOE OSA and DOE-RL defined major activities and milestones (Figure 3)
- Defined the Functional Design Criteria for the program
- Completed 95% of the conceptual design
- Submitted National Environmental Policy Act documentation to DOE for approval

Plans

For the remainder of this fiscal year, work will be concentrated on completing the Conceptual Design Report in March and completing preliminary design by the end of this fiscal year. Construction will begin in FY 1989 and assembly operations in FY 1991.

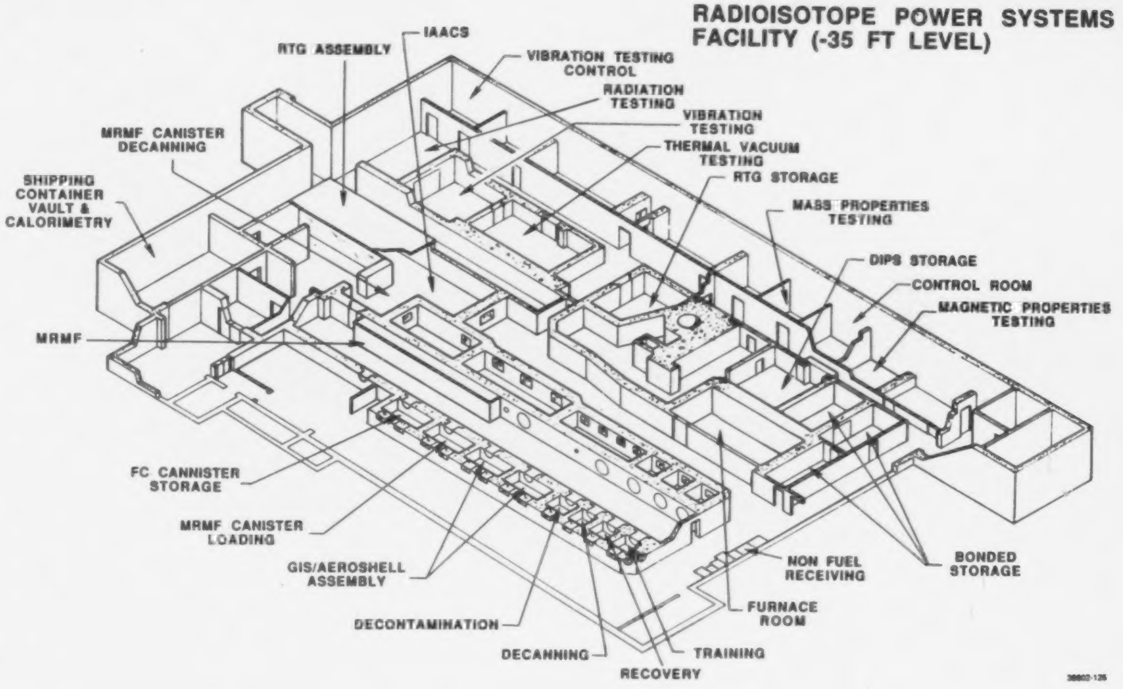

RADIOISOTOPE POWER SYSTEMS FACILITY (-35 FT LEVEL)
RTG ASSEMBLY
IAACS
VIBRATION TESTING CONTROL
RADIATION TESTING
VIBRATION TESTING
THERMAL VACUUM TESTING
RTG STORAGE
MASS PROPERTIES TESTING
DIPS STORAGE
CONTROL ROOM
MAGNETIC PROPERTIES TESTING
MRMF CANISTER DECANNING
SHIPPING CONTAINER VAULT & CALORIMETRY
MRMF
FC CANNISTER STORAGE
MRMF CANISTER LOADING
GIS/AEROSHELL ASSEMBLY
DECONTAMINATION
DECANNING
RECOVERY
TRAINING
FURNACE ROOM
NON FUEL RECEIVING
BONDED STORAGE
39802-125

Figure 1

General Purpose Heat Source (GPHS) Module Assembly

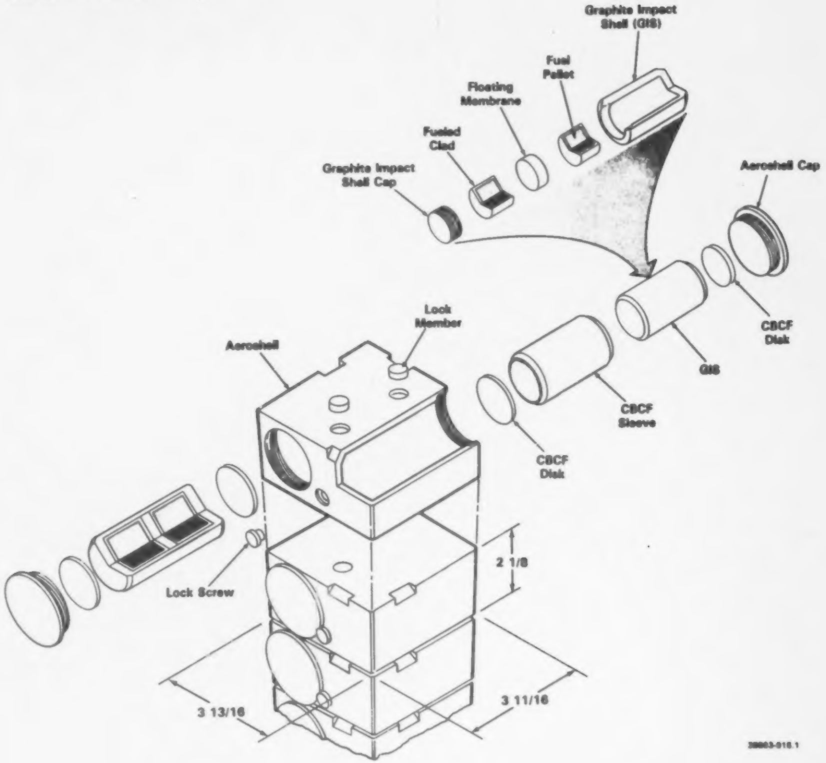

Graphite Impact Shell (GIS)
Fuel Pellet
Floating Membrane
Fueled Clad
Graphite Impact Shell Cap
Aeroshell Cap
CBCF Disk
GIS
CBCF Sleeve
CBCF Disk
Lock Member
Aeroshell
Lock Screw
2 1/8
3 13/16
3 11/16
39863-016.1

Figure 2

PANEL 2 DISCUSSION

Mr. STALLINGS. Thank you, Dr. Arnold. I appreciate that testimony.

The Chairman has just slipped for a moment to vote, as you heard. Hopefully, this will be last vote of the day and we can get on with something a little more permanent.

I have a couple of questions. I'm going to be a little bit provincial here and address those to a good friend of mine, Dr. Till, who is very involved in the Argonne-West operation. We appreciate the work that you've done out there, Dr. Till. It's a pleasure to have a very competent operation going, that you have been running in the last few years.

Let me just ask a couple of questions.

Now, I understand that EBR-II just completed perhaps the most successful operating year. How did it's performance compare with that of our commercial reactors?

Dr. TILL. Well, indeed, it has. The last calendar year the capacity factor of EBR-II, which is defined in the simplest possible way, just how many days of full power operation divided by 365, was 82 percent, which compares to perhaps 58 percent, 57-58 percent typically for the average of commercial reactors. It indicates how reliable the liquid-metal systems can be, and I note that FFTF from Mike Korenko's testimony had 77 percent. Something of that kind. Very high also.

Mr. STALLINGS. Is it fair to say that if your IFR demonstration at the EBR-II complex is in operation in fiscal year 1990 the U.S. can regain a leadership position in LMR development?

Dr. TILL. Well, I think so. There are clear signs that other major programs are thinking in our direction. There was a recent article in a Soviet journal in November of 1987, official journal, by the head of their fast reactor program, and he went through the status of their program what directions they should take.

The two main direction changes in his conclusions were, first, to adopt a process similar to our PYRO process, and secondly, to sharply increase their work on metal fuel.

Now, we have clearly a three- or four-year lead on them, and if we can get on with that addition at Argonne-West, we will have put ourselves very substantially in the lead.

Mr. STALLINGS. Thank you.

Mr. Morrison, do you have some questions?

Mr. MORRISON. Well, I could talk a long time with these folks, and Bill Snyder, thank you for being here. I was impressed when I visited Sandia with the work you're doing which, maybe if you've listened to my questions today, sort of provides some answers, and that is, are we really following the right path?

I'm impressed with what you shared with me there and what you've included in your testimony, and that is, maybe we're being let down more by some things we think of as fairly standard—valves, pumps—some of the hardware that's not related to the nuclear industry at all that is in fact providing some of this lack of reliability that is plaguing our nuclear power industry today.

From your testimony—I guess I don't have so much of a question. It's just a statement, Mr. Chairman, and to our excellent staff hoping that we can maybe build something into the system so that we look very carefully at what we should be doing to encourage American industry to respond to those obvious failures of what we're doing.

You suggested a commission of some type in your testimony.

Mr. SNYDER. May I comment, Congressman Morrison. I've looked, in fact, at the balance-of-plant components and their contribution to the unavailability in nuclear power plants.

My first estimate is that in light water reactors, as they exist today, the first 100, the unreliability in what are assumed to be standard components in water technology, the pumps and the valves, the valves alone are costing the U.S. nuclear industry $1.2 billion per year in unavailability.

Those valves are not just in the nuclear industry. They're in the fossil industry, the petrochemical industry. My best estimate, it's a very crude estimate, is that the lack of improving the quality of valves and systems that handle liquids, particularly in the water and the petrochemical industry, are costing this country somewhere around $100 billion a year in lost revenues.

We have not put any R&D into sophisticated componentry for handling liquid systems, and particularly water, for at least 20 years. Now, in contrast to the success of the EBR–II in the sodium systems, we've put a lot of money in the balance-of-plant components, specific pumps and valves for sodium. But here we have an industry of light water reactor and many other industries that utilize water at high pressure, high temperature and we have just a plethora of problems with that componentry and we put no R&D in that area.

So, there is in fact an imbalance in our emphasis of how we treat the balance of plant from industry to industry and from system to system.

Mr. MORRISON. Dr. Arnold, do you want to respond?

Dr. ARNOLD. I'd like to comment just based on my own experience. I was 15 years in the light water reactor business. I certainly agree with what Mr. Snyder said.

I would just make a comment, though, that what has happened in that business is that there is not a continuing effort of the type you would have if you had a continuing process of designing and developing new plants. We were, in fact, improving components while we were designing plants. But the process essentially stopped to the extent that we no longer had new plant orders and no longer had the sustenance for the continuous engineering effort you'd have if you were designing and building airplanes. You're not just designing the conceptual design of the new airplane, you're also improving all the things that go into it. As time goes on and you get feedback from the field, there's no longer the sustaining business that sustains that effort.

So, if in fact there is to be a sustaining effort of that sort, it's got to be something more than just the industry does because there is no longer an industry in the United States that at least in other than doing a few conceptual designs, is designing substantial numbers of new plants.

Mr. **Morrison**. Excellent point. It's a problem. I don't know how we wrestle with it because we're having trouble with the financing of the number of more basic research programs.

Mr. Chairman, what do you want to do on the vote?

Mr. **Stallings**. I think you and I had better go vote. Let's adjourn for about two or three minutes. Mrs. Lloyd will be right back. She is on her way. If you gentlemen will just stay very close by. She has a series of questions that she wants to ask, and I'm sure Mr. Fawell does as well.

We stand adjourned for maybe five to ten minutes.

[Brief recess.]

Mrs. **Lloyd**. Dr. Arnold, I want to address the first question to you. Do you see any technical problems associated with converting the FFTF core from an oxide fuel to a metal fuel?

Dr. **Arnold**. The answer is not of an overwhelming nature but there are some things that have to be checked out in the course of any change like that to satisfy yourself that the engineering is proper and that you will in fact meet the same safety standards you did in the first place. With that proviso, the answer is "Yes, it can be done, provided appropriate testing is done".

Mrs. **Lloyd**. Mike, would you like to comment on that?

Dr. **Korenko**. I guess I'll give you the perspective of the guy who runs the plant.

Mrs. **Lloyd**. That is always valuable.

Dr. **Korenko**. We really agree with the vision of the LMR, the potential of the metal fuel to contribute to that, and when running a reactor, I can't run it on visions. I have to have real fuel that works. I have a safety envelope. I have NRC independent review. We need a certain source of funds to do this transition. We think we can do it. There are technical surprises that we can overcome but not without funds. Our 1989 guidance, there is no funding for metal core transition. How can we do it?

It is elementary that unless that funding exists, there is no metal core transition. It is an academic question.

Again, to answer your question directly, a metal core can work in FFTF, but it does need demonstration of certain technologies within our capability of doing.

Mrs. **Lloyd**. How much do you need, what kind of funding are we discussing here?

Dr. **Korenko**. The minimum funding that we have been able to identify from the issues that have already come to the surface are around $5 million, which is part of the $17 million request. We don't know if there are other surprises. We really are lifting up one rock at a time, trying to do a technical transition.

Mrs. **Lloyd**. Do you need all that money in 1989?

Dr. **Korenko**. Yes, because we will need more in 1990.

Mrs. **Lloyd**. What do you see in the out year?

Dr. **Korenko**. I don't have the actual needs in 1990. I would rather get that to you in a short while.

Mrs. **Lloyd**. If you would provide that for the record.

Dr. **Korenko**. We have an independent review board set up, which I asked to be set up, to be headed by Clark Gibbs and a number of people across the country examining this from a neutral perspective. They are making recommendations to the Department of Energy on March 23. On the basis of those independent assessments, we will come up with the minimum cost path through this. I might add the National Academy of Sciences is also reviewing this and their early indications are we just don't have enough resources there to do this transition. If it doesn't work, we run out of fuel.

Dr. ARNOLD. I would just mention that is part of the continuing study of the DOE's Class A reactors.

Mrs. LLOYD. Very good. In some of the testimony you have presented today, we have heard the expression that there is a possibility of utilizing metal-fuel reactors to reduce our high-level radioactive waste. What level of effort would be required to demonstrate this potential, to alleviate high-level radioactive waste problems? I would address that to all of you.

Dr. ARNOLD. We mentioned that most recently in our testimony.

Dr. KORENKO. We have a formal proposal with the acronym CURE, which is Clean Use of Reactor Energy. That is a two-year demonstration that focuses on the concept of actinide fuel reactor work, one of the many demonstrations in FFTF and FMEF to get us over the surface. We think that is a two-year demonstration. We were proposing an up-front, approximately $2 million to get the study rolling across the country and then a $12 million, next increment, because you are doing this in terms of pilot chemical testing and hot cells. That is relatively expensive.

We want to be very, very careful on not overstating this. I keep saying that, as a nuclear community person, because it is possible for people to get over excited about this and then use it as an excuse to say we don't need a repository. We are not making those kinds of claims. We really want to go through it, the potential is out there, and it is exciting us but we rather keep it low key and just do the technical demonstration and study.

In two years, I think we may have something that will be pretty exciting. At this point in time, it is——

Mrs. LLOYD. You don't feel now is the time to make a pronouncement on the technology?

Dr. KORENKO. It is tempting but no.

Mrs. LLOYD. It is very tempting to me.

Dr. Till?

Dr. TILL. Let me make a comment on that, in the same area of the desire to process the fuel, take the long-lived actinides out, put them back in the reactor again. The PYRO process we think may be able to do that. The problem—it has always been feasible. With wet chemistry, you can separate those things out and put them back into the reactor again. The economic studies over the years say it wasn't economic to do it. The primary one was a study done at Oak Ridge perhaps ten years ago.

If the PYRO process will work, it will work almost naturally doing that and the amount of money required to establish that, whether it will or will not, to establish the chemistry, is trivial. It is something we will be working on. It is in the range of a few hundred thousand dollars. It is getting one, two or three good chemists to work on it.

Mrs. LLOYD. Thank you very much.

Mr. Snyder, what has been the Department's response to your recommendations for the formulation of a high-powered commission to help formulate nuclear power policy?

Mr. SNYDER. I've discussed the matter with Mr. Rossin before the position was taken over by Ted Garrish. I've not had an opportunity to discuss the matter with Mr. Garrish. I have in fact had a number of conversations with other members of DOE. While they have not endorsed the specific features of the method of implementation that I have presented in the written testimony, they endorse the idea emphatically in the sense that we are all searching for that vehicle, that means by which we can identify a platform for commercial nuclear power development, that all of us can rally around and try to stop the fusion or the diversity of views that is sort of grasping at straws. I think many of us are thrust into that at the moment.

I am convinced very much that under the present sort of infrastructure we have in the nuclear community, its legacy, that somehow we have to formulate a platform in which there is a general consensus and we have to include in the development of that platform those who would be our worse enemies, so to speak.

I come from a point of view that it is very frequently that people, for example, in the environmental movement, it is not so much that they oppose what you want to do, but when they are brought in at the 12th hour and offered a fait accompli, you threaten their power base and that is just not smart politics.

Mrs. LLOYD. That is a very interesting observation. Thank you very much.

Mr. Morrison?

Mr. MORRISON. Thank you, Madam Chairman. I had a minute or two before we voted to talk with Mr. Snyder about their program, about his proposal. I did want to follow up on a basic question that does really relate to Dr. Till as well as to my two good friends from our Westinghouse activities at Hanford.

There is a concern, and I hope a growing confidence in metal fuel and I'd like to start by asking Dr. Till how he feels about the progress that he now sees with metal fuel and maybe of greatest importance to our programs at Hanford with FFTF, the ability to produce that metal fuel.

Dr. TILL. Congressman Morrison, I feel very confident now of the ability of even the tertiary fuel to perform extraordinarily well in an reactor. That is to say even the fuel that contains plutonium. The assemblies in EBR-II, as I say, have burned up 15 percent. There were no failures.

We have the lead assembly in FFTF itself at full length. Having said that, the confidence that I have in the binary fuel, that is just uranium and zirconium, is even greater. It is a fuel with even greater margins.

I recognize that with the existing licensing or operational framework that FFTF operates in, that certain cases have to be made about the safety, and we at Argonne in fact have been putting considerable resources in cooperation with Westinghouse/Hanford to try to help make those cases. I believe myself they will be perfectly successful.

As to the confidence in the ability of the plant to operate with that fuel, and the ease or difficulty in making the safety case, I believe, on all of these things are perfectly handleable.

As far as making the fuel, we are set up to make the fuel. All we need is more technicians to push it through. That is why I have a request for a couple million dollars and that will go strictly for manpower to produce that 30 subassemblies or so a year that we need to produce for FFTF.

Mr. MORRISON. I appreciate your optimism.

Dr. Arnold or Dr. Korenko, I know there is concern about that fuel supply and perhaps the concern is as much the need for an assurance for an ongoing role for FFTF. I was somewhat disheartened by the response that I got earlier in my question to DOE officials on the future, not just FFTF but the other reactors. I have sensed your concern on cutbacks taking you almost to the point of concern about reactor safety and operation.

Let's talk about the fuel issues, since that is where we are now. Do you share the optimism that we are hearing from our good friend from Argonne?

Dr. ARNOLD. I have no reason to differ with regard to the optimism. The concern we have is over sufficient funding to do the work that has to be done to satisfy our review committees and quasi-regulators that in fact everything has been done when we make that switch over. It is an issue of time and money.

Mr. MORRISON. How about the issue of supply?

Dr. ARNOLD. I have no reason to question what Chuck is saying. With regard to being able to produce the fuel.

Mr. MORRISON. Is there any concern with the dedication of the Department of Energy to make sure that supply is there?

Dr. ARNOLD. Yes, because it boils down to the issue of money.

Mr. MORRISON. It is after 5:00. You can say anything you want.

Dr. ARNOLD. It boils down to an issue of providing the funding to do the work that has to be done.

Mr. MORRISON. For those of you operating FFTF, the fuel, at least in the transition, has it been operating up to your hopes and expectations?

Dr. ARNOLD. I will ask Mike to comment on that.

Dr. KORENKO. Right now, in terms of the metal-fuel operation, we really don't have that much metal fuel in our reactor. I believe Chuck when he says he will deliver the fuel. I can have all the fuel there but I can't put it in a reactor unless it is safety qualified. It is those qualification tests that are critical to be able to use the fuel. That is where the concern is, because the funding has been eroding for a number of years, if you watched our fuel supply inventory, it has been eroding with it. The way it is scheduled now, unless we get additional funding, we are going to absolutely run out of fuel in two years, out of gas.

We need to feed the pipeline with more metal fuel but it has to be qualified metal fuel, qualified being able to fit within our reactor safety envelope.

Dr. ARNOLD. It is really not something that is outside our control except for the funding to do it.

Mr. MORRISON [presiding]. I hope that is within our control. Thank you very much, gentlemen.

We recognize the gentleman from Argonne.

Mr. FAWELL. Thank you.

Dr. Till, I am pleased of course to see the Department of Energy has continued to support the IFR program which I talk about quite a bit and I compliment both DOE and Argonne for advancing so quickly along this promising new path.

It seems as though, even though the President's budget provides an increase for Argonne's overall reactor funding, and I think this has been mentioned to a degree, the scope of the IFR program has also been considerably increased. You have indicated there are some additional funds that you believe are necessary.

What is the effect this additional work would have on the IFR program?

Dr. TILL. First of all, let me say Congressman Fawell, I congratulate you on your very successful day yesterday.

Mr. FAWELL. Yes, I think we saw each other late last night at my victory party.

Dr. TILL. The main scope that has been added, within DOE's allocation of monies to us, the expectation that we can produce the FFTF fuel, and it is by $2 million of technician help, that's one thing. If we don't get that, then something breaks, either the fuel doesn't get made or the R&D work doesn't get done. The second thing is the $4 million that I have identified in connection with the modification of the facilities. That is done for simplicity. It is engineering work that needs to be done to meet what are now evolving regulations that DOE is putting on that are changing day by day, putting on the plutonium operation in that complex.

The second part of that is, again, DOE is encouraging us very, very strongly to put manpower onto the safety analysis of FFTF. This is all additional scope. We want to carry it out. We do need that amount of money to do it and also carry on the IFR development program that as you say I believe has been very successful in the past few years.

Mr. FAWELL. This question has been partially answered, with the technological advances made possible by the IFR program, new metallic fuel, the new processes, the increased safety margins to name a few, has interest been stirred internationally in the IFR concept? I know you made reference to the Soviet journal.

Dr. TILL. Yes. More concrete than that, the Japanese, referred to earlier, their agreement with the Department of Energy runs out this year and is being renegotiated. There are four specific items in it, in addition to signing the umbrella agreement.

The main one, the biggest one as far as dollars are concerned, is the Japanese request to obtain IFR technology, both fuel and process. The amounts of money that they are offering to pay essentially Argonne to do this are reasonably substantial. I have been asked to serve on the Joint Coordinating Committee for that agreement. I will of course do so.

There is very concrete interest on the part of at least certain advanced nations in the IFR technology.

Mr. FAWELL. Just one other question. Does the metal technology that is of course the central feature of the IFR have other possible applications in addition to the IFR itself and other than what you have referred to today?

Dr. TILL. Yes, I think it does. Of course, the thing that is current right now is the need for new production reactors and the metal technology can be re-optimized, specifically for the production application so the technology is related to the IFR technology, but the product looks quite different. For example, a production reactor that has a low inventory, scientifically perfectly feasible metallic target, has a number of very desirable features, if the Nation decides to pursue it. But the point is that it is a very flexible technology and you can optimize it in a number of ways. The IFR is simply just one optimization item.

Mr. FAWELL. Thank you very much. I have no further questions, Mr. Chairman.

Mr. STALLINGS [presiding]. Thank you, Mr. Fawell. Mr. Morrison, do you have any other questions or comments?

Mr. MORRISON. No, thank you.

Mr. STALLINGS. Gentlemen, thank you very much for your testimony and your responses. We do appreciate your input into this Committee.

[Question and answers for the record for Mr. Snyder and Dr. Till follow:]

A. Wm. Snyder
Director
Exploratory Nuclear Power Development

Sandia National Laboratories
Albuquerque, New Mexico 87185

April 21, 1988

Subcommittee on Energy
Research and Development
Room B-374
Rayburn House Office Building
Washington, D. C. 20515

Attention: Lottie McCaw-Daniels

Reference: Letter, Marilyn Lloyd, Chairman, Subcommittee on Energy Research and Development to A. W. Snyder, dated April 1, 1988

As requested, enclosed are responses to the written questions posed by the Subcommittee subsequent to my testimony of March 16th on Nuclear Fission.

I appreciate the opportunity to contribute to the formulation of an agenda for nuclear fission energy development that will have greater assurance that the nuclear option will be viable and can be exercised with public confidence.

Sincerely,

Responses to Questions from House Subcommittee on ER&D

1. **Question:**

If a commission were constituted to help develop nuclear energy policy as you suggest, what period of time do you believe would be required for such a commission to perform its function and make its recommendations?

Response:

Similar undertakings by commissions, councils, committees, etc. on topics of comparable complexity have nominally taken 18 months from authorization to final published report. The duration can range from 12-24 months depending upon the urgency, driven usually by the timing of the first significant, intended use of the report. The time required to mobilize commissions of quality people with diverse and preexisting commitments is usually underestimated. The time from authorization to the first full commission assembly is nominally three months. The time to write, edit, critique, reedit, approve and print the final report is optimistically three months. The substantive deliberations of the commission would thus be encompassed in nominally a 12-month calendar period.

2. **Question:**

Your testimony suggests that it will be necessary to reestablish public confidence in the reliability of the existing operating nuclear power plants in this country.

Part 1:

What do you foresee as the role of the federal government in performing the necessary tasks to establish this reliability?

Response:

The role of the federal government, including national laboratories, would be that of a partner with organizations of the nuclear industry, including institutes, NSSS vendors, and balance-of-plant component suppliers in an alliance to support and encourage, through research, development, and demonstrating improvements in the reliability of selected nuclear power plant components and/or classes of components that have been identified as dominant contributors to unplanned outages of plants. These unplanned outages result in challenges to plant safety systems, increase electric energy production costs and erode public confidence in the quality and safety of plants. It must be stressed that the roles of the federal government and of industry are complementary; each"brings to the table" different but mutually reinforcing technical experience and resources. They would share in common the objectives of achieving excellence in the reliability performance of U.S. nuclear power plants, strengthening nuclear-electric power as an end-use energy supply option and contributing to an effort to reestablish the U.S.'s preeminence in nuclear-electric power.

The cumulative results of federally supported research and development at the national laboratories, particularly in non-nuclear technology, constitutes a resource of advanced materials, potentially applicable preexisting parts and components, and product ideas that have not been tapped and applied to the potential benefit of the greater reliability of U.S. nuclear power plants. Meetings with NSSS vendors and the Electric Power Research Institute have identified numerous opportunities. The role of the federal government would be to authorize and fund a concerted, integrated approach to put in place laboratory-industry technology alliances to advance the reliability of selected components. The safety and economic consequences to nuclear-electric power through these alliances would be far greater than can be attained through the unidirectional and more passive approaches to technology transfer.

Part 2:

In your view, is the existing program within the Department of Energy's Light Water Reactor R&D program directed towards this goal?

Response:

In my view, existing programs within the Department's LWR R&D program will not reach these goals.

Part 3:

What would be the role of the Sandia National Laboratory in this overall program that you are proposing, and have you commenced any activities in this area?

Response:

Sandia National Laboratories would be a participant, along with other national laboratories, in several technology alliances with firms/organizations of the nuclear component supply industry. The character of the participation of a national laboratory would be determined by the character of its ongoing research, development, and engineering responsibility, and the applicability of the resulting technology to component reliability improvements in nuclear-electric plants. Sandia, as an advanced engineering laboratory, has developed in its role as a defense laboratory an extensive technical base in materials and components that has been identified as having direct applicability to the nuclear-electric power industry. Complemented by its extensive experience in the reliability analysis of nuclear power plants, Sandia could be very effective as the technical management center on behalf of the DOE/NE to integrate several other national laboratories into a planned and focussed effort to improve the reliability performance of U. S. nuclear power plants. We have commenced exploratory activities in this area collaboratively with EPRI and NSSS vendors. The activity has great promise for improving the intrinsic safety, economic performance and public acceptance of nuclear-electric power.

Part 4:

What is the nature of any activities that you may have presently under way or planned in FY 1989 towards reestablishing public confidence in nuclear power as an energy resource?

Response:

As detailed in the March 16 testimony, I have proposed a reexamination of the contemporary U.S. nuclear power agenda with the objective of reaffirming the current agenda or revising the agenda to pursue a modified direction. I have proposed the reexamination as a result of diagnosing the current condition of U.S. nuclear-electric power, being careful to distinguish between symptoms of the current conditions and the causal factors. I have concluded that (1) the assumptions, attitudes, and de facto policies that influence current directions for U.S. nuclear power do not account for current social, political and economic realities; (2) numerous of the undesirable conditions of nuclear-electric power are traceable to the non-nuclear subsystems of nuclear-electric power plants; and (3) continued emphasis predominantly on advancing the nuclear technology of fuels, alternative primary coolants, etc. is not a balanced program that will ameliorate the current conditions, one of which is public confidence in plant safety and economic viability. I am confident that the proposed reexamination of the nuclear power agenda, properly constituted with members and conducted under the aegis of an organization free of the burden of advocacy will lay a platform which if implemented and sustained will move toward reestablishing public confidence in the technology and plants.

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue, Argonne, Illinois 60439

April 6, 1988

The Honorable Marilyn Lloyd
Chairman, Subcommittee on Energy
Research and Development
Committee on Science, Space,
and Technology
U.S. House of Representatives
Rayburn House Office Building,
B-374
Washington, D.C. 20515

Attention of Lottie McCaw-Daniels

Dear Madam Chairman:

In your letter of April 1, you asked for our response to a question that arose from your Subcommittee's hearing on March 16, 1988. I appreciate the opportunity to provide you with the enclosed response, and thank you again for the invitation to testify before your Subcommittee.

Respectfully yours,

Charles E. Till
Associate Laboratory Director
Engineering Research

CET:vag
Enclosure

ADDITIONAL QUESTIONS FOR DR. TILL
HEARING BEFORE THE SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
March 16, 1988

Are institutional changes necessary in the way electric power is distributed and marketed in order for a utility to willingly take on the challenge of reprocessing metal fuels in addition to the operation and maintenance of a nuclear power reactor? If so, how is your program taking into account the institutional barriers to the deployment of technology? IFR?

I do not know whether institutional changes would be essential for a utility reactor operator to process IFR fuel on-site and return it to the reactor. As far as the necessary skills are concerned, it certainly is true that any utility with a PWR or BWR is into chemistry in a big way now, just doing what is necessary for water chemistry in the present plants. So I think it is conceivable that utility operators of the future would not find the IFR fuel processes an insurmountable obstacle. On the other hand, we have very experienced utility, reprocessing, and chemical industry executives on our IFR Peer Review Committee who have expressed the opinion to me that if the IFR process turns out to be as good as it seems "there will be service companies springing up all over to do this for the utilities as there'll be a lot of money to be made."

In all this there is an implicit assumption that the processes would be carried out on-site. This is not necessary of course, although I believe it may be politically desirable. The processes, similar to the present aqueous reprocessing plants, could equally well be carried out at a separate centralized location. In this we are at least no worse off. But the tremendous advantage the electrochemical process has, that sets it apart from traditional processes, is that it promises to be economic even for the first plant or the first few plants. One can see, for this process, some way of proceeding that does not involve huge subsidies just to get breeder deployment started.

Actually, I think the real situation is that no one today can foretell what the institutional framework for large-scale electricity generation in this country will be two or three decades from now. The present institutions are clearly in trouble. It is in this future context that the IFR will be important if it is developed. I believe there is a very good case that, if successful technically, the IFR characteristics will ease institutional difficulties faced by nuclear power, and this in turn will reflect to the substantial benefit of the reactor owner and operator.

Mr. STALLING. This concludes our hearing for the day. The Subcommittee will meet again tomorrow morning at 9:30 a.m. to receive testimony from non-Government witnesses on the same subject, the DOE's proposed nuclear fission budget. The hearing will be in Room 2325 of the Rayburn Building.

This meeting is adjourned.

[Whereupon, at 5:30 p.m., the Subcommittee recessed, to reconvene at the call of the Chair.]

1989 DEPARTMENT OF ENERGY AUTHORIZATION

THURSDAY, MARCH 17, 1988

House of Representatives,
Committee on Science, Space, and Technology,
Subcommittee on Energy Research and Development,
Washington, DC.

The Subcommittee met, pursuant to notice, at 9:30 a.m., in Room 2325 Rayburn House Office Building, Hon. Marilyn Lloyd [Chairwoman of the Subcommittee] presiding.

Mrs. **Lloyd**. The Subcommittee will come to order.

Good morning, ladies and gentlemen. Happy St. Patrick's Day to you.

Before I begin my statement, I must ask unanimous consent, pursuant to House rules, that the Subcommittee permit today's proceedings to be recorded by the public, and hearing no objection, so ordered.

This is the second day of hearings on the Department of Energy's proposed fiscal year 1989 budget for Nuclear Fission Energy Research and Development.

As mentioned yesterday, the DOE proposes five programs in this budget, totaling $352 million in expenditures. Activities include development of nuclear-electric power systems for use in space; the development of liquid metal and high temperature gas reactors; the operation and the maintenance of facilities at our National Laboratories to support various fission R&D activities; the production and testing of isotope power systems for use in space; and finally, the improvement of light water reactors.

We hear today largely from non-Government witnesses, although one of the witnesses on the second panel represents the Oak Ridge National Laboratory. We have three panels. The first on the high temperature gas reactor program; the second on all the advanced reactor activities; and the third panel on the health of our nuclear engineering programs at our universities.

I would like to yield now to the gentleman from Washington, the distinguished ranking Republican, certainly a very hard-working member of this Committee, that I enjoy working with on this Committee, Mr. Morrison.

Mr. **Morrison**. Thank you, Madam Chairman. I think our start on this particular subject area went very well yesterday, and I look forward to the presentations in the specialized areas today, and I think I will probably keep any other comments very limited to the question opportunities. Thank you.

Mrs. LLOYD. Thank you.

PANEL 1: HIGH TEMPERATURE GAS REACTORS

Mrs. LLOYD. Our first panel of witnesses is Mr. Linden Blue, who is Vice Chairman of the Board of General Atomics. Mr. Blue and his brother are entrepreneurs who have demonstrated the courage of their convictions in promoting and funding the next-generation nuclear technology that is very close in being inherently safe; that is the high temperature gas reactor. I think they certainly made a very wise choice, and I encourage them to continue their aggressive marketing of this technology.

The second witness on the panel is another good friend of mine, whose opinions and advice I value very highly, Dr. Mike High of the Tennessee Valley Authority. It's certainly good to see you again, Mike. Dr. High is the Director of Energy Demonstration and Technology for TVA, and he is here today representing the Gas Cooled Reactor Associates of which TVA is a member.

And finally, the third witness is Mr. Robert P. Will, whom we are pleased to welcome again this year. Mr. Will represents the Metropolitan Water District of Southern California, where the HTGR might find its very next commercial application, and we heard some interesting testimony last year about the Water District's plan, and I am sure the testimony this year will be equally as interesting.

We welcome you gentlemen to the Subcommittee this morning. We have your written statements and you may proceed as you wish.

Mr. Blue.

STATEMENT OF LINDEN S. BLUE, VICE CHAIRMAN OF THE BOARD, GENERAL ATOMICS, LA JOLLA, CA

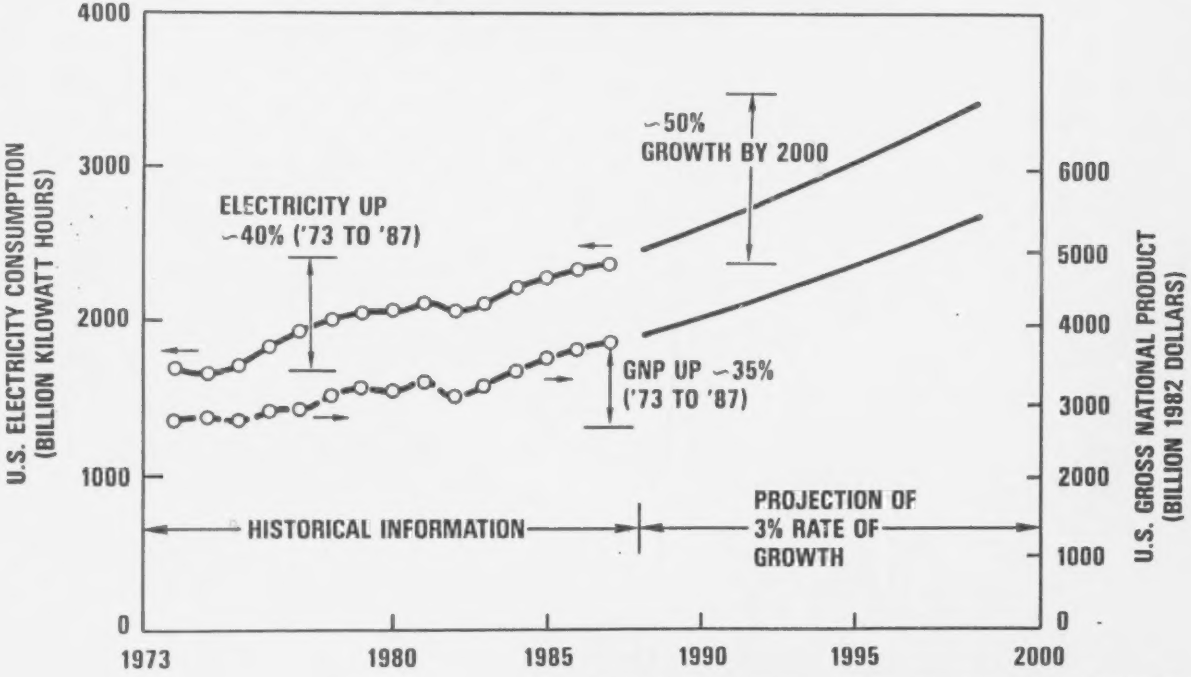
Mr. BLUE. Thank you, Madam Chairman, members.

I would like to put my remarks in three sections. First, a little discussion of our perception of the problem, some of the alternatives that we are faced with, and, finally and most importantly, the progress that we have made because of the program that you have made possible for us in 1984.

First, if I may use the chart, this is the chart, and I have some hard copy which I will pass out to you at the end of the hearing, which shows the correlation between growth in GNP and use of electrical power in 1973 to the present day, and it shows that GNP grew about 35 percent, while the electrical power grew 40 percent, a very interesting correlation in lines in the relationship between these two.

GENERAL ATOMICS

U.S. SHOULD CONSUME 50% MORE ELECTRICITY BY 2000



. . . SHOULD REQUIRE ~200 GW(e) ADDITIONAL BASE LOAD CAPACITY BY 2000

I-491(1)
2-26-88

And if you project these on out at a 3 percent growth rate—some would say 2½, some would say more than 3—you'd come up with a conclusion that we should consume 50 percent more by the turn of the century, which isn't that far. There's a 50-percent growth in electrical power before the turn of the century, sort of an awesome figure, when you consider that it would essentially require about 200 gigawatts of power additional baseload by that point in time.

That is the equivalent of, say, 200 Shoreham- or Seabrook-type reactors. Now I think it might be fair to say that none of us would anticipate 200 more reactors of that kind in this timeframe, so it suggests that there is a problem that's coming down the road. And we say should consume, because the alternative is not economic growth, and I think that is something that nobody wants to see.

Now there are, of course, all kinds of alternatives, but the principal ones we have to take advantage of is at least consumption of oil, more use of coal. The problem with oil, of course, is we are already importing about $45 billion a year in oil and gas, and all that would do is aggravate it. More use of coal—coal will obvicusly play an important part in the equation, but it can't do it all. More nuclear. The problem there is, as we have seen, it is doubtful that we will have 200 more plants like Shoreham and Seabrook, particularly in that timeframe. And totally unacceptable, the fourth alternative, is simply not to grow and not have increasing standards of living.

GENERAL ATOMICS

THE U.S. MUST CHOOSE:

1. MORE RELIANCE ON MIDDLE EAST OIL
2. MORE USE OF COAL
3. MORE NUCLEAR
4. LOWER STANDARDS OF LIVING

I-491(1)
2-26-88

In fact, obviously we would have a lower standard of living. Now that is not an acceptable alternative. There are many other things that you could throw up there—solar, conservation. All these things will be done, but in terms of realism, by the end of the century, we are going to have to rely on these three areas for our power.

Now we know here that this can only be a part. I think the principal reason is the perception of the safety equation that such as Shoreham would give us. Recently Dr. Lawrence Lidsky of MIT, I think has made a very interesting addition to the debate, you might say, on nuclear safety. He defines three areas of safety, or three levels of safety, and just roughly speaking, the third level of safety is what we have currently with our water reactors.

Now, in my opinion, these are safe reactors, but they also are reactors based on the defense-in-depth, immediate-operator action to forestall any problems, and they are susceptible to operator error, or major structural problems.

Now this is Dr. Lidsky's definition. Now the advanced water and perhaps liquid metal technologies we believe can give us Level 2 safety. In Dr. Lidsky's opinion, only the HTGR can give Level 1 safety.

GENERAL ATOMICS

U.S. CAN CHOOSE:

- LEVEL 3 SAFETY
- LEVEL 2 SAFETY
- LEVEL 1 SAFETY

Now again, I would emphasize, maybe we don't need Level 1. Maybe Level 3 is all right. Again, I happen to think that our nuclear industry is safe. We have had some problems here. We have had some problems other places in the world, but on balance it is safe. But still, if we are talking progress, because of your program which was instituted four years ago, we now concede that Level 1 safety is achieved.

Well, what are we doing to provide this Level 1 safety? In the past year we have made very substantial progress in the technical areas, to the point that I can state categorically that there are no longer any technical feasibility questions. We have made substantial progress in the design of the plants. The design has been reviewed by the NRC, by the ERAB panel, and in conclusion, universally is there are no feasibility issues still out there. The work has been very well received by these independent bodies.

What are we doing to get on to the design phase? In this past year we have formed a formidable team with Combustion Engineering and Bechtel to make sure that the best possible preliminary design and final design work is done.

Now when people say, "Well, that sounds like an interesting team, what does it bring to the equation?" Well, it brings in Combustion, the most professional reactor builder in the world. They have the best record for availability of any reactors in the country, and that is the kind of reputation which we expect to have brought to modular HTGR's when they are installed.

In addition to that, on the design side, we have made or we have entered into a memorandum of understanding with Siemans, the large German company, for the commercial development of these reactors. And Siemens brings two very important pieces to the equation.

First of all, they are committed to making a 10-percent match of anything the Department of Energy contributes to this program in FY 1989. Those are totally private funds. That is a very substantial indication of their conviction that this is the right technology for the future.

Second, and perhaps considerably more importantly, they have indicated that when the design is complete and when the construction is ready to go, they will be willing to make the industrial or commercial guarantees of performance that will be necessary to launch a commercial plant.

Now that is a major commitment, and it can only be taken by a huge company, which Siemens is. So that again is a tremendous statement of their confidence in this technology and their expectation that this can be a commercially viable technology, and their desire to participate in it with us.

So I think this is a strong suggestion of where we are headed, and obviously I don't need to tell you that having Siemens as a partner to exploit international markets would be of tremendous advantage, particularly considering the size of the international markets. And when we consider the size of those markets, the importance of the United States participating in them, we have to remind ourselves that probably 75 percent of all the reactors built will be outside the United States. They must be American technology, and that's what we are driving for, and I would say that in order to achieve this first level of safety, we need the kind of commitment that GA is giving it and that Combustion Engineering is giving it, and Bechtel and Siemens, and if we do, we can come up with a technology that is Level 1 in every respect, and I would submit that for a country that expects to remain a number one world power, that's the kind of technology we need. Make this program go forward at the kind of pace that is needed in the world. We believe that a minimum of $35 million this year is required for the program.

[The prepared statement of Mr. Blue follows:]

STATEMENT FOR THE RECORD

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOP
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLO
UNITED STATES HOUSE OF REPRESENTATIVES

FY 1989 DOE AUTHORIZATION
HIGH TEMPERATURE GAS-COOLED REACTOR PROGR

LINDEN S. BLUE
VICE CHAIRMAN OF THE BOARD
GENERAL ATOMICS

MARCH 17, 1988

Madame Chairman and Committee Members:

I am Linden S. Blue, Vice Chairman of the Board of General Atomics, and I am pleased to have the opportunity of appearing before you today on behalf of the Modular High Temperature Gas-Cooled Reactor, or ModularHTGR, program.

In the letter of invitation to address the Subcommittee, several questions were suggested. These questions concerned the need and applications of ModularHTGR technology, the timing of the need, and the business arrangements which are being made to allow industry to address this energy need. These questions provide an excellent structure within which I can illustrate:

- Why the vendors, utilities and governmental experts involved in the program believe the need for the ModularHTGR is now;
- How several major international corporations have aligned their capabilities to offer the U.S. and the world an energy technology which is safe, economical, and environmentally sound; and
- What role the government can play to catalyze the commercial availability of the ModularHTGR.

Today is the threshold of the 21st Century. Our energy policy decisions will impact the availability of scarce resources, of economic development, and of food supplies. What path are we choosing for the country and the world in the 21st Century? Will it be one of increasing pollution and political strife as nations consume their limited fossil resources with accelerating competition for the remaining resources? Will it be a century in which technological advances which could alleviate many social and environmental concerns remain undeployed? Will the economies of the twentieth century powers falter in the 21st Century as they fail to capitalize on their technological currency in trading for the raw materials they require? While no energy source, technology, or international peace plan alone guarantees a productive 21st Century, we must make our best efforts to place at future decision-makers' disposal those options which can address the problems which are already apparent. The ModularHTGR addresses many of the concerns for energy sources.

The foresight of this committee, which in 1984 urged the HTGR program to develop an inherently safe nuclear power system which is economical and based on near-term available technology, has now been transformed into a conceptual design with exceptional promise. We are now charged with transforming this conceptual design into the concrete and steel of an operating power station and thereby presenting a viable energy option for the 21st Century.

What is the current state of Modular HTGR techology?

The Modular HTGR is an advanced, high-efficiency nuclear power source in which each module has been sized, configured and designed such that the core cannot melt. Furthermore, the fuel cannot release radionuclides even under conditions representative of the most severe accidents, including a sustained total loss of coolant. The long-term safety of the system, based on inherent and passive features only, gives the ModularHTGR unprecedented siting flexibility and eliminates any technical requirement for evacuation plans.

Through the efforts of industry and government, not only has virtually all of the underlying basic technological development been completed but components of the size and type incorporated in the ModularHTGR — such as the fuel, pressure vessels, heat exchangers, and auxiliary systems — have been tested and even employed in similar, if not more adverse conditions. The conceptual design for a four-module, 538 MWe station has been completed. This conceptual design represents ~20% of the engineering required through the start up of an initial four-module facility and indicates that the ModularHTGR will meet the safety, licensing, operability, maintainability, and economic requirements of both the government and the utility industry.

Regulatory review of the conceptual design has now been underway for almost 18 months. The Preliminary Safety Information Document (PSID), Probabilistic Risk Assessment (PRA), and Regulatory Technology Development Plan (RTDP) have been under NRC review which was initiated in September of 1986. The nine subsequent meetings with the NRC have been very productive and I anticipate that NRC will issue a positive licensability statement in the very near future.

While much technical work remains to be done on the ModularHTGR, the design has progressed to the point that there are no open technical feasibility questions. The next step is for industry and government to continue to work together to reduce and quantify the political and economic uncertainties for the vendor and purchaser of the initial plant such that the commercial sector can shoulder subsequent deployment.

How does the ModularHTGR fit into U.S. needs for commercial energy and export products?

The enthusiasm for the ModularHTGR stems not only from the positive social and economic impact that it will have in the next two decades, but also for the longer term influence which it must have. While arguments swirl about shorter-term electrical and economic growth rates of a few percent in the United States, there is little disagreement that the energy demands of a politically stable, developing world will require massive quantities of energy during the 21st Century. Most of this new energy must come from environmentally acceptable and economically competitive sources, sources which are not yet deployed or even available for deployment. There is also little disagreement that the northeastern states and some states in the southeast have a more immediate need and must expand generation capacity well beyond existing plants prior to 2000. The statement and letter presented by Gas-Cooled Reactor Associates and their utility members are evidence that the ModularHTGR fits the needs of the U.S. electrical generation facility market.

World electrical capacity requirements in the next century will increase by tens of thousands of GWe, assuming even the most conservative growth rates. Requirements for additional industrial process heat will be of the same magnitude. The ModularHTGR can address both electrical and process heat needs and, because of its simplicity and inherent safety, it is an attractive export item to the developing countries. These developing countries will be the large majority of the trillion dollar annual energy facility market expected by mid-century. Typically, these countries lack large numbers of trained personnel and the industrial infrastructure necessary to construct and operate complex power facilities. The simplicity and safety of the ModularHTGR, while desirable in the U.S., is mandatory in much of the export market.

By the middle of the 21st Century, world electrical capacity can be expected to exceed 20,000 GWe. At these generation levels, the use of combustion techologies will not be environmentally acceptable. Even clean combustion with its CO_2 production and the resulting "greenhouse effect" will have to be dramatically restricted.

Fission reactors should be the electrical energy source of choice for at least the first several decades of the twenty-first century. Given the long lead times involved in major power projects, the U.S. utilities must begin soon to contract for much of the 100 GWe to 200 GWe of new and replacement power which will be needed on-line prior to 2005. If the ModularHTGR is to afford the utilities a publicly, politically, and environmentally acceptable nuclear option, government and industry must define and fund a program which provides for a construction permit in the early 1990's and a subsequent initial project.

In addition to U.S. electrical needs, certain areas of the country must also expand their fresh water resources. . The ModularHTGR, with its modern steam conditions, unique siting flexibility, and low fuel cost, is an attractive heat source for a desalination facility. Considering these factors, the Metropolitan Water District of Southern California has sponsored a feasibility study for a large-scale seawater desalination facility using the ModularHTGR's waste heat. Such a four-module facility would meet the water needs of ~700,000 people and the electricity needs of ~400,000 people. The inherent safety would permit the plant to be sited on the coast where it would be needed.

The ModularHTGR must move forward now so it can displace resource squandering oil and gas-fired electrical plants in the U.S. and to meet the rapidly increasing demand in developing countries. We cannot afford to be blinded by the short-term, artificially low price of oil and, particularly, natural gas. A well coordinated, joint effort by government and industry which includes multi-year commitments can deliver the ModularHTGR in a timeframe to have an initial module on-line by the mid-1990's and permit the technology to meet a portion of the energy capacity additions needed in the first decades of the 21st Century.

In the past two years, China, Bangladesh, Italy, the Soviet Union and several other countries have exhibited a strong interest in importing ModularHTGR technology or facilities. Technical delegations, technology exchange proposals, joint studies, and requests for quote have been received by ModularHTGR vendors in both the U.S. and Germany. Completing the ModularHTGR development will allow the U.S. to be a major factor in meeting the international demand for new electrical generating facilities with a safe, simple, environmentally acceptable product which would substantially improve our balance of payments.

How does the ModularHTGR technology fit into government requirements?

In addition to its role in assisting industry in devloping and maintaining a secure, cost-effective domestic energy supply, the government has identified a specific need for a New Production Reactor (NPR) in the mid-1990's. Just as the ModularHTGR holds the potential to assist the U.S. in securing its energy supply, competitive position, and domestic employment, its excellent neutron economy, high thermal efficiency, safety margins, and advanced stage of development, make the ModularHTGR the country's best choice for the NPR. The excellent neutron economy of the graphite moderated reactor allows the MHTGR-NPR to meet desired production quantities at modest thermal power levels. The high thermal efficiency and the high system availability resulting from multiple modules maximizes the electric revenue available as a by-product from the materials production operation. In fact, the electrical revenue from an eight module facility will be $10 to $20 billion (depending upon the location) over the 40 year life of the plant, thereby dramatically reducing the cost of the production materials over the other alternatives. The inherent safety will provide the surrounding public and their political leaders with the assurance that production operations will not endanger or interfere with their lives under any circumstances. The advanced stage of development of the MHTGR-NPR, manifested in the target particles and ongoing licensing review, will minimize the delays to be expected in designing the qualifying (licensing) the fuel, targets, and safety systems.

Except for differences in the fissile particle enrichment and minor differences in the fuel blocks, all major components of the MHTGR-NPR (i.e., circulators, steam generators, pressure vessels, turbine generators, etc.) are the same as required for the commercial plant. For this reason, the NPR will directly advance the commercial deployment effort. The MHTGR-NPR will also establish and exercise the industrial infrastructure which would subsequently deploy the ModularHTGR for civil applications. In the NPR selection, the government has the opportunity to multiply the effectiveness of their defense expenditures by substantially assisting in the development of an advanced commercial energy source in much the same way as the Air Force catalyzed the commercial passenger aircraft industry with its development of the KC-135 refueling tanker which became the Boeing 707.

The belief that the ModularHTGR is the best choice for the NPR is shared by the members of the MHTGR-NPR supply team — specifically:

- General Atomics
- Combustion Engineering
- Stone & Webster Engineering Corporation
- Burns & Roe

This impressive group of companies have combined their capabilities to offer the MHTGR-NPR to the Department of Energy/Defense Production. We believe this option will not only meet the government's requirements for materials production in the late 1990's, but will also supply electrical power and catalyze a viable, new energy source for the country.

What strategy is proposed and what business arrangements have been made to facilitate direct civilian commercialization?

Direct civilian commercialization of the ModularHTGR will require significant multi-year commitments by government and industry. The current industry team of the DOE nuclear steam supply design program includes General Atomics, Combustion Engineering, and Bechtel. A major architect/engineering firm will also be selected by DOE for the energy conversion area (conventional balance of plant). The suppliers involved possess all the resources, technology, and technical skills required to design and construct commercial power stations and have expressed an interest in being party to future commercial offerings once the political and licensing uncertanities have been reduced or quantified. The objective of the current DOE sponsored design and development effort is to reduce and quantify these noncommercial uncertainties by completing the design, technology and licensing to support an initial project. This information will be used to establish the economic viability and to obtain a construction permit. Industry will accept an increasing fraction of the commercialization costs as the goals are approached.

The goals of the current DOE program are necessary, but not sufficient for commercialization. Commercialization will require the construction and successful operation of one or more modules. In discussions between GCRA, their utility members, and the vendors, it has been established that the initial facility must have long-term commercial value, but it must also phase the financial investment. Both requirements can be achieved by designing, planning, and contracting for a four-module, 538 MWe facility in which the successful operation of the first module triggers the subsequent investment in and construction of the remaining three modules. Such a strategy will deliver a facility of sufficient size to be commercially viable, thus permitting the commercial value to be financed.

The first steps toward an initial ModularHTGR project have now been taken with the signing of a Memorandum of Understanding between General Atomics and Siemens/Interatom of Germany to vigorously pursue the project. Other participants in the U.S. program are expected to join this initial project vendor arrangement in the near future.

The addition of Siemens/Interatom to the ModularHTGR vendor team is a very large step forward. First, Siemens, as one of the world's largest companies, brings the financial strength necessary to propose such a commercial offering. Second, their experience as the architect-engineer and vendor for dozens of large fossil and nuclear power facilities around the world provides the team with recent experience in building these types of facilities in a reasonable six to eight year timeframe. Third, Interatom's interest in this arrangement stems from their own work in High Temperature Gas-Cooled Reactors and demonstrates their informed belief that the ModularHTGR will be an important part of the world's energy future. Siemens' commitment to the program is evidenced by the attached statement and their willingness to cost share even in pre-commercial studies.

The General Atomics, Siemens/Interatom arrangement calls for the vendors to offer the initial ModularHTGR power project to interested utilities or other wholesale power purchasers. The vendors are willing to consider alternative types of offerings including, under appropriate conditions, fixed price offers which will be competitive with other new, large generating facilities. The vendors will therefore accept the commercial risks associated with construction and qualification performance of the facility. The vendors will also consider the role as plant operator, should the purchaser wish to contract for such services. The ModularHTGR vendor team fully expects to present a viable offering to selected U.S. utilities before the end of 1988.

What role must the government play to catalyze the commercialization of the ModularHTGR?

As previously stated, industry is prepared to accept the challenge of commercial deployment of the ModularHTGR once the political and licensing uncertainties have been reduced and defined. The teaming arrangements, cost sharing, and other costs being borne by industry are evidence of this acceptance. To catalyze commercialization, the government must provide major assistance in the preliminary and final design leading to the construction permit and initial project. Following the issuance of the construction permit industry can accept the burden of fabrication and construction, if the government will provide development funding for the first-of-a-kind (FOAK) engineering and fabrication. Government commitment to these design and development activities for the facility will permit the ModularHTGR vendor team and purchasing utility to initiate a project on a largely commercial basis. After the initial facility, industry can aggressively introduce the ModularHTGR into the marketplace.

Based on our cost estimates, the government can expect to invest less than one-third of the funds which will be required for the initial ModularHTGR facility. Such an investment by the government is warranted by the impact that such an environmentally benign, non-fossil fuel exportable energy source will have in the future.

In closing, it is encouraging to note that the unequaled safety advantages of the ModularHTGR are being recognized by influential individuals outside the program. Recent publications by Dr. Lawrence Lidsky of the Massachusetts Institute of Technology point out that a ModularHTGR type facility can achieve his definition of level one safety:

- No need for active systems in event of subsystem failure.
- Immunity to major structural failure and operator error.

General Atomics believes these characteristics will permit the ModularHTGR to serve as a focal point for a new public and political consensus which will allow nuclear power to help meet the energy needs of the 21st Century.

Budget Recommendation

The ModularHTGR private initiative which has been described can be successful only if all parties will make commitments which are binding for the ~10 years required to bring all four units on line. Multiple year budgets are necessary to provide a stable climate for private investment.

For FY'89, I recommend a budget which is sufficient to support the preliminary design and associated additional licensing review, to continue the technology development work at the national laboratories, to lend credibility to the private initiative, utility support, and international interest, to display seriousness to potential export customers, and to illustrate the commitment to assisting industry in developing new, inherently safe, environmentally benign energy sources. These activities will require at least $35 million in FY'89. This funding must increase as the development and private initiative progresses. It is also crucial that the NRC be sufficiently funded to continue their licensing review of the ModularHTGR.

Madame Chairman, I appreciate the opportunity to summarize the plans and potential of the ModularHTGR for you and the subcommittee. As we combine the foresight demonstrated in 1984 by this subcommittee with industry's recognition of the social and economic potential of this technology, I expect to see a significant improvement in our energy future.

STATEMENT FOR THE RECORD

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES

FY 1989 DOE AUTHORIZATION
HIGH TEMPERATURE GAS-COOLED REACTOR

ADOLF J. HUETTL, DIPL.-ING.
VICE PRESIDENT
SIEMENS AG, KWU GROUP

MARCH 17, 1988

SIEMENS/INTERATOM STATEMENT TO THE U.S. CONGRESS

Siemens AG, a publicly held corporation, and Interatom GmbH, a wholly-owned, independent daughter company of Siemens AG, both of the Federal Republic of Germany, respectfully wish to enter the following statement in support of the U.S. Modular High Temperature Gas-Cooled Reactor (MHTGR) Program to the U.S. Congress.

Siemens and Interatom recently entered into an agreement with General Atomics to jointly explore commercialization of the MHTGR. This private sector initiative will complement the US-DOE Program in planning a way to combine efforts to develop, license and construct the first MHTGR plant for the U.S. domestic utility market.

In the Federal Republic of Germany we, Siemens/Interatom, are expending about $15 million annually on the advancement of closely related Modular High Temperature Reactor technology. In pursuit of our joint venture with General Atomics, Siemens and Interatom together have committed private resources totalling over $2M during fiscal year 1988. Substantial portions of these funds will be used to evaluate and advance the design technically. The results of this effort will be available to and benefit the U.S. DOE Program. The remaining portion of the private funds will be applied to estimate costs, perform economic analyses, plan project financing, and undertake project development.

We have been involved in the design and development of reactor technology for over 30 years and in 1979 we developed the Modular High Temperature Gas-Cooled Reactor. Of course, our experience and technology would be made available to a U.S. project through our participation.

Our commitment to the U.S. Program is motivated by our confidence in gas-cooled reactor technology in general, and in the particular design and safety features embodied in this concept. We remain convinced of the global needs for safe nuclear energy in the years to come, and the role which gas-cooled reactors likely will play in satisfying these needs.

Siemens and Interatom recognize that successful commercialization of advanced nuclear technology will require concerted commitments on the part of both Government and private sectors. Therefore, we are prepared to demonstrate our support of the Modular HTGR Program by committing private funds again for FY 1989 in the amount of at least 10% of the MHTGR budget that U.S. Congress may provide. Hence, together with General Atomics, significant private resources will complement the U.S. MHTGR budget during this period, as long as utility interest in this private initiative is sustained. We strongly endorse commercial and utility recommendations to continue and increase government support to a level commensurate with completing the preliminary and final design, which will lead to the private sector's commitment for construction of a real project in the foreseeable future.

Mr. STALLINGS [presiding]. Thank you, Mr. Blue. Dr. High, if you'd like to proceed.

STATEMENT OF DR. MICHAEL D. HIGH, DIRECTOR OF ENERGY DEMONSTRATIONS & TECHNOLOGY, TENNESSEE VALLEY AUTHORITY, CHATTANOOGA, TN, ON BEHALF OF THE GAS-COOLED REACTOR ASSOCIATES [GCRA]

Dr. HIGH. Thank you. Madame Chairman and members of the subcommittee, I am appearing today here on behalf of the Gas-Cooled Reactor Associates. My apologies for Mr. Walker, the Chairman of the Board, who cannot be with you today.

I do direct research and development for the Tennessee Valley Authority, and as you know in that respect TVA's interest in long-term generation is longstanding. At the present time, we have a major hand in the Clean Coal Technology with the fluid-bed development program.

We think and strongly believe that the successful development of any new-generation technology in today's utility environment must focus on the actual building and operation of a prototype system in order to gain the field experience necessary for us to completely understand the construction and operating costs before getting the capital required for adding new investment.

I'd like to make a note that, in addition to my active role in GCRA, I represent TVA on several other reviews of advanced reactor programs which all together have come under closer scrutiny by the electric utility industry in the past year. And out of those reviews I'm still convinced that the gas-cooled reactor should play a major part for the U.S. electric utility and users. As you know, many of the actions needed to ensure safety and reliability of the current generation of light water reactors is time consuming and costly. Advanced reactor systems which have other safety and reliability features are badly needed.

I think the foresight of this Committee four years ago in recognizing the benefits of MHTGR should be acknowledged. I think the support for the HTGR continues to grow in the electric utility business, and in fact, attached to my written testimony is a signed joint statement by the 29 utilities representing the vast majority of the capacity in this country.

This statement I think indicates a very real awareness by the electric utility industry that when capacity needs again rise that the nuclear option has got to be viable; there has to be an advanced reactor of some type.

I won't enumerate the advantages of the gas-cooled reactor. You've heard these all before, but obviously the passive safety aspects of it are well-documented. All that leads to lower cost, ease of compression, siting, corresponding cost reductions and ease of operation.

I also in my role interact with EPRI quite heavily and have been a proponent of EPRI increasing their funding for the advanced reactor programs, and their program since they represent the electric utility business, since they are in the R&D sector.

I think the expected benefits of the gas-cooled reactor, although they are convincing on paper, have got to be proven. As the GCRA and the MHTGR program participants have consistently maintained, our goal is to conduct a prototype project before the turn of the century to ensure that the MHTGR is a viable option. Three activities have been carried out over the past year and significant progress made in those. Number one, a fairly detailed conceptual design carried out to identify the list of the development activities that require a licensing support; things like fuel qualification, circulator development and core physics data verification.

In addition to that, there has been a well-defined program defining what a prototypical plant would look like for licensing verification and what that expansion would mean to a commercial venture. And as Mr. Blue just pointed out, the third activity was to develop a strong vendor supply team, and he did an excellent job of explaining where we are in the industry on that point.

In regard to the first-of-a-kind development activities, I think substantial progress has been made. A conceptual design has been completed and assessments have been made and I think we just reinforce what we believed about the MHTGR; the challenges can be met, and as Mr. Blue has stated, we don't see any uncertain feasibility issues at this time.

For example, current assessments of the HTGR design were brought to the fore by a week-long utility review based on a panel that had over 350 years of experience in the electric utility business and significant experience in the gas-cooled reactor business. That panel reviewed and I think confirmed that we really don't see any—technical feasibility issues down the road for gas-cooled reactors.

I think the most commanding aspect of the MHTGR program over the last year has been support of the NRC review. While the schedule for this has slipped some from the July to April-May timeframe this year, the review has generally confirmed NRC's perspective of the passive safety features of gas-cooled reactors that we have spoken to in the past. The timely resolution of the remaining issues and issues of the final Safety Evaluation Report by the NRC we think will be crucial to the program.

The second effort involves proof of the MHTGR's economic viability. In cooperation with MHTGR program participants, GCRA has been supporting development of a project initiative to build and operate a prototypical MHTGR. Overall, the initial project deployment costs, including a first of a kind arrangement are $1.75 billion. This would be a plan for four modules. I might note that we think that roughly $700 million of that would be for Units 2 through 4 with first-of-a-kind costs going to the prototype plant.

One such funding arrangement that might be considered by the Department of Energy and the U.S. Government would be something like the support for advanced reactors generally like the Clean Coal Technologies—and I'd like to put that idea in front of this Committee for consideration at some point in time.

Also crucial to the development of the MHTGR is stable Government support, including that from Department of Energy. We have consistently recommended a phased-commitment approach structure for the advanced reactor programs. Each phase could mandate an increasing threshold of non-DOE support necessary from the private industry necessary to carry this out. With this approach, I believe the prospects of significant private-sector involvement in a prototype plant could greatly be enhanced.

You will note in the Joint Statement that we recommend $35 million for the DOE program for MHTGR. These funds will continue to be used for first of a kind preliminary design technology and licensing development activities. This level of support is important to establish a balanced approach and resource base within the program to foster the project initiative development. We think the MHTGR program is at a critical stage of early preliminary design and project development with a strategy framework that stabilizes adequate DOE support and thereby provides a solid basis for broad participation by non-DOE and private sector parties must be established. And this Subcommittee's support I think is very crucial to that end.

With that, I will close my remarks and thank you.

[The prepared statement of Dr. High follows:]

STATEMENT SUBMITTED FOR THE RECORD
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES

FY-1989 DOE AUTHORIZATION FOR HIGH TEMPERATURE GAS-COOLED REACTOR PROGRAM

DR. MICHAEL D. HIGH
DIRECTOR OF ENERGY DEMONSTRATIONS & TECHNOLOGY, TENNESSEE VALLEY AUTHORITY
AND MEMBER OF BOARD OF DIRECTORS FOR GAS-COOLED REACTOR ASSOCIATES

Madam Chairman and Members of the Subcommittee, my name is Michael D. High. I am Director of Energy Demonstrations and Technology for TVA and I am appearing here today on behalf of the Gas-Cooled Reactor Associates (GCRA). As you know, TVA is a federal agency and instrumentality which among its various activities manages a utility system with the largest generating capacity on the North American continent. Our interest in the development and demonstration of advanced technologies for the generation of electricity to serve the ever-expanding needs of industry and the public has been long standing.

At the present time, we have a major involvement in the development of advanced coal combustion technology. The Joint Atmospheric Fluidized Bed Project at TVA's Shawnee Plant has moved effectively through the design and construction phases and plant startup is scheduled this year. We strongly believe that the successful development of any new generation technology must be focused on the actual building and operating of prototypical systems in the field in order to gain the necessary experience to launch a viable commercial option.

In advanced nuclear technologies, TVA conducted an extensive review in 1983 and 1984 of several concepts and identified the High Temperature Gas-Cooled Reactor (HTGR) as the most promising. As a result, TVA joined GCRA with the intent of participating in the development and deployment of the HTGR as a future nuclear generating option. Since then, I have represented TVA on the GCRA Board and have taken an active role in guiding the overall GCRA activities, including the adoption of the Modular HTGR (MHTGR) as the single focus of the HTGR Program.

I would like to add that in addition to my active role in GCRA, I represent TVA in various capacities in the direction and review of the other U.S. advanced reactor programs, which all together have been under much broader utility scrutiny during the past year. I am convinced that the MHTGR technology is best suited for the majority of the U.S. utility/users. This view is supported by the experience with other advanced reactor programs. As you know the many actions needed to ensure the safety and reliability of the current generation of light water reactors have been time consuming and costly. Advanced nuclear systems for which safety and reliability can be assured with less time and cost are clearly needed.

The foresight of this Committee in recognizing the benefits of the MHTGR over four years ago and the Committee's steadfast support for the HTGR Program are respectfully acknowledged. Support for the MHTGR continues to grow as the need for a superior, second generation of nuclear power and the impressive capabilities of the MHTGR are increasingly recognized worldwide. The bases for and the representation of the broad utility/user support for the MHTGR is reflected in this year's Joint Utilities' Statement on the MHTGR Program. This year's Joint Statement is signed by 28 utility executives that collectively represent an impressive cross section of the U.S. utility leadership and a significant fraction of the Nation's generating capacity. In the current period of nuclear aversion throughout the utility industry, our Joint Statement is considered a significant input to the Congressional Committees with oversight responsibility for the MHTGR Programs at the DOE and the NRC. A copy of the Joint Statement is attached to my statement for the Congressional Record.

For added emphasis, I would like to expand on the key expected benefits of the MHTGR that are responsive to the pervasive issues that confront nuclear power expansion in the U.S. These benefits may be summarized as follows:

- Eased licensing and siting plus enhanced public acceptance associated with the passive safety design concept that is both demonstrable and transparently evident.
- Reduced investment risks associated with equipment malfunctions and operator error.
- Reduced capital and operating costs plus enhanced reliability/availability associated with elimination of many complex, safety-related engineered components and systems.
- Reduced field labor, construction schedule and cost uncertainties plus enhanced standardization and learning benefits due to the large content of shop fabrication.
- Easier financing due to low capital requirements plus reduced financial risk associated with a flexible match-to-load-growth requirements.
- Simple fuel management without the need for recycle or consideration of nuclear proliferation policy issues.
- Modest resource demands for the development effort.

However, "expected" benefits must be proven with a convincing prototypical Lead Project. As GCRA and the MHTGR Program participants have consistently maintained, our goal is to conduct such a Lead Project before the turn of century in order to assure the MHTGR option when major capacity expansions are currently projected. To accomplish this goal, three distinct but related efforts are involved. The first effort deals with the first-of-a-kind design, technology and licensing development risks which are being addressed through the ongoing DOE MHTGR Program. The second effort addresses the economic risks of plant costs and performance. GCRA has consistently supported the establishment of an MHTGR Program that would address these risks through a multi-party effort to build an initial prototypical plant. The third effort involves the formation of a capable vendor entity that will financially support and deliver the initial plant as well as provide follow-on commercial plants and services.

With regard to the first-of-a-kind development, substantial progress has been made during the past year. The conceptual design has been completed and the assessments indicate that the MHTGR design can meet the challenging utility/user requirements established by GCRA. In our view, there are no technical uncertainties that threaten the feasibility of the MHTGR concept. This statement draws from the continual staff involvement in the development programs and the periodic utility reviews and assessments. For example, as part of the culminating assessments of the MHTGR conceptual design, GCRA conducted a week-long utility design review with emphasis on operation, maintenance and the management support requirements for owning an MHTGR plant. The review panel consisted of thirteen senior utility representatives with over 350 years of cumulative experience, including extensive LWR experience as well as past plant supervisors for the Peach Bottom I HTGR plant and current managers from the Fort St. Vrain HTGR plant and the Heysham Advanced Gas Reactor Plant in the U.K. Such utility reviews assure that the MHTGR development effort will produce a product that meets utility requirements plus reflect the utility commitment and interest in the MHTGR development process.

The most commanding aspect of the MHTGR Program during the past year has been the support for NRC's review of the MHTGR design and related safety analysis and licensing criteria. While the schedule for culminating this effort has slipped from January 1988 to the April/May timeframe, the review has generally confirmed the passive safety features of the MHTGR and has established an effective dialogue between the MHTGR Program and the NRC. The timely resolution of the remaining issues and issuance of a final Safety Evaluation Report by the NRC will be crucial to the ongoing Program.

The second effort involves proof of the MHTGR's economic viability. In cooperation with the MHTGR Program participants, GCRA has been supporting the development of a Project initiative to build and operate a prototypical MHTGR. Through ongoing Project development efforts, a definition of the requirements and scope, a detailed estimate of the costs and schedules, an arrangement for government/industry cost sharing, and the overall benefits and limitations of a cooperative MHTGR Project are being established. Through this effort, an optimal approach for an initial Project has evolved. It is based on an initial commitment for a one-module prototype plant that provides performance results for the subsequent expansion to a four-module lead plant which will have long-term commercial value. Ongoing Project activities are focused on identifying and developing multiple sites and applications as options for such an initial project in parallel with the development of cost/risk sharing arrangements as the bases for an MHTGR Project initiative and proposal for Government support. Overall, the initial Project deployment cost, including first-of-a-kind development activities, is in the range of $1.75 billion (1988 dollars) and the proposed Government support is in the range of $500 million (1988 dollars).

The third effort has advanced on two fronts during the past year. Within the DOE MHTGR Program, the corporate team of General Atomics, Combustion Engineering and Bechtel are functioning as a vendor entity to advance the preliminary design of the MHTGR nuclear island. In addition, cooperative vendor efforts are under way with Siemens/Interatom, the MHTGR pioneer from the Federal Republic of Germany, to support a Project initiative in the U.S. These combined efforts are expected to culminate in a strong MHTGR vendor entity that GCRA feels is crucial for the Project initiative effort and the delivery of subsequent MHTGR commercial plants.

Also crucial to the furtherance of an MHTGR Project initiative is stable Government support, including DOE. GCRA and the MHTGR Program participants have consistently recommended a phased commitment approach structure for the advanced reactor programs. Each phase could mandate an increasing threshold of non-DOE support necessary to release the DOE funding provided by Congress. The added motivation to accomplish agreed-upon milestones within agreed-upon funding splits and funding caps would foster improved programmatic progress as well as stability. With this approach, I believe the prospects of significant private sector involvement in the Lead Project would be greatly enhanced.

For FY-1989, the Joint Statement recommends that Congress provide $35 million for the MHTGR Program within DOE's Advanced Reactor Program. These funds will be used to continue the first-of-a-kind preliminary design, technology and licensing development activities. This level of support is important to establish a balanced technical resource base within the Program plus foster the Project initiative development.

Madam Chairman, the MHTGR Program is at a critical stage of early preliminary design and Project development. A Project strategy framework that stabilizes adequate DOE support and thereby provides a solid basis for broad participation by non-DOE and private sector parties must be established. This Subcommittee's continued support is crucial as we work toward that end.

GCRA GAS-COOLED REACTOR ASSOCIATES
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Chairman

March 11, 1988

Honorable Robert A. Roe
Chairman, and Members
House Committee on Science,
Space & Technology

Honorable Tom Bevill
Chairman, and Members House
Appropriations Subcommittee
on Energy & Water Development

Honorable Morris K. Udall
Chairman, and Members
House Subcommittee on
Energy and the Environment

Honorable J. Bennett Johnston
Chairman, and Members
Senate Committee on Energy and
Natural Resources

Honorable J. Bennett Johnston
Chairman, and Members
Senate Appropriations Subcommittee
on Energy & Water Development

Honorable John B. Breaux
Chairman, and Members
Senate Subcommittee on
Nuclear Regulation

Dear Messrs. Chairmen and Members:

On behalf of the supporting signatory utilities, I respectfully submit a Joint Utilities' Statement that provides added bases for Congressional support for the Nation's Modular High Temperature Gas-Cooled Reactor Program.

Sincerely,

R. F. Walker

R. F. Walker, Chairman & CEO
Public Service Company of Colorado
Chairman, Gas-Cooled Reactor Associates

Enclosure

cc: Honorable John S. Herrington
Secretary, Department of Energy

Honorable Lando W. Zech, Jr.
Chairman and Members,
Nuclear Regulatory Commission

JOINT UTILITIES' STATEMENT ON THE MHTGR PROGRAM

The Modular High Temperature Gas-Cooled Reactor (MHTGR) deserves a high priority within the overall U.S. advanced reactor programs on the basis of three key reasons:

- The MHTGR is an attractive generation alternative that is consciously responsive to the technical, economic and institutional issues currently restraining the expanded use of nuclear power by U.S. utilities.

- The MHTGR provides expanded potential for nuclear energy to serve future process energy needs, ranging from water desalination to coal/synfuel applications.

- The MHTGR is an attractive nuclear export product that is responsive to nuclear proliferation issues, offering world-wide nuclear leadership for the U.S.

Underlying these reasons is a world-wide need for safe, clean, economical energy. With particular emphasis on improved public acceptance, the MHTGR offers a greater degree of inherent and passive safety than any other nuclear reactor concept being developed for commercial power generation. For all accidents considered for public safety evaluations, the MHTGR is self-limiting to conditions well below fuel failure limits. That translates into enhanced safety margins whereby, in the event of an accident, the offsite doses are well below the regulatory limits requiring public evacuation or even sheltering. The inherent and passive design features also provide important financial risk reductions to the plant investors and ratepayers.

Utility/user support and interest continues with the increasing acknowledgment that the MHTGR can provide significant benefits and that new generation will be required in many parts of the country by the turn of the century. Organized utility/user support for and participation in the MHTGR Program is through Gas-Cooled Reactor Associates (GCRA). In addition, the utilities' Advanced Reactor Corporation has given their solid endorsement for continued MHTGR development following their review of DOE's Advanced Reactor Program.

Despite budget constraints, the MHTGR Program made substantial progress during the past year. The conceptual design was completed, the licensing review conducted by the NRC is validating the benefits of passive safety features and economic evaluations continue to show competitive energy costs. Overall, the development work has continued to engender confidence that the design can meet the challenging utility/user requirements developed by GCRA.

JOINT UTILITIES' STATEMENT ON THE MHTGR PROGRAM (Con't)

Since funding levels have been constrained, priority has been given to the critical design, licensing and technology development activities. The intent is early resolution of the issues confronting the deployment commitment for the MHTGR. For example, key to the realization of MHTGR's passive safety benefits is the NRC's acceptance of its safety concept and related licensing criteria. The final results of the safety assessment of the MHTGR conceptual design by the NRC, leading to their Safety Evaluation Report currently planned for this spring, will be an important factor in the Lead Project development activities planned for 1988.

Preliminary design of the nuclear island has begun within the DOE Program by a corporate team of General Atomics, Combustion Engineering and Bechtel. A balance-of-plant design entity should be in place by mid-spring. In addition, cooperative efforts to develop a Lead Project initiative have been initiated with Siemens/Interatom, the pioneer of the MHTGR concept in the Federal Republic of Germany. Technology development continues through the MHTGR Lead Laboratory at Oak Ridge.

In spite of the continued progress and the potential National benefits, the Administration's proposed budget for FY-1989 does not include adequate resources for the MHTGR Program. Accordingly, we respectfully recommend that Congress provide $35 million within DOE's Advanced Reactor Program in FY-1989 for the continued preliminary design, licensing and technology development of the MHTGR. This budget level is needed to establish a balanced technical resource base and to foster a Lead Project initiative. With success, these efforts will result in a multi-year commitment by all parties leading to NRC's issuance of a Preliminary Design Approval of the MHTGR design followed by a construction permit for the Lead Project. In addition, it is important that the NRC's budget be adequately funded to assure the timely support of the ongoing licensing development process for the MHTGR.

It is further noted that the MHTGR requires a relatively modest effort to complete the front-end design, licensing and technology development required to support a Lead Project that could be deployed by the turn of the century. Further, the Lead Project may be deployed with the initial capital commitment limited to one module. This allows experience feedback for optimizing the subsequent modules of the Lead Plant as well as invaluable support for the NRC's design certification for subsequent commercial plants.

This Joint Statement is respectfully submitted to the Congressional Committees with oversight responsibility for the Nation's nuclear power development programs as evidence of the broad utility/user support for the MHTGR Program.

JOINT UTILITIES' STATEMENT ON THE MHTGR PROGRAM (Con't)

R. F. Walker

R. F. Walker, Chairman & CEO
Public Service Company of Colorado
Chairman, Gas-Cooled Reactor Assoc.

James L. Everett

James L. Everett, Chairman, Pres. & CEO
Philadelphia Electric Company
Vice Chairman, Gas-Cooled Reactor Assoc.

Les Balmer

Les Balmer, Chairman
Metropolitan Water District of So.Calif.

J P Bayne 2/29/88

J. Phillip Bayne, President & CEO
New York Power Authority

Bob Bergland

Bob Bergland, Executive Vice President
National Rural Electric Coop. Assoc.

Merle L. Borchelt, Vice Chairman
Central and South West Corporation

John P. Bundrant

John P. Bundrant, President & COO
Public Service Company of New Mexico

Mark DeMichele

Mark DeMichele, President & COO
Arizona Public Service Company

E. L. Draper Jr.

E. Linn Draper, Chairman, Pres. & CEO
Gulf States Utilities

W. R. Esler, President & COO
Southwestern Public Service Company

E. James Ferland, Chairman, Pres. & CEO
Public Service Electric & Gas Company

David J. Fogarty

David J. Fogarty, Exec. Vice President
Southern California Edison Company

Robert M. Ginn

Robert M. Ginn, Chairman & CEO
Centerior Energy Corporation

LARRY HOBART

Larry Hobart, Executive Director
American Public Power Association

John J. Kearney

John J. Kearney, Senior Vice President
Edison Electric Institute

L G Kuncl

L. G. Kuncl, Manager, Nuclear Power
Nebraska Public Power District

JOINT UTILITIES' STATEMENT ON THE MHTGR PROGRAM (Con't)

W. S. Lee, Chairman & CEO
Duke Power Company

William J. Lindblad, President
Generating Division
Portland General Electric Company

George A. Maneatis
George A. Maneatis, President
Pacific Gas & Electric Company

George V. McGowan, Chairman & CEO
Baltimore Gas & Electric Company

Edward F. Mitchell, President & COO
Potomac Electric Power Company

Robert J. O'Connor
Robert J. O'Connor, Chairman & CEO
Idaho Power Company

A. J. Pfister, General Manager
Salt River Project

Justin Rogers
Justin Rogers, President & CEO
Ohio Edison Company
& Chairman, Pennsylvania Power Company

Marvin Runyon
Marvin Runyon, Chairman, Board of Dir.
Tennessee Valley Authority

Jack E. Thomas, Exec. Vice Pres. & COO
San Diego Gas & Electric Company

James E. Tribble, President & CEO
Yankee Atomic Electric Company

John A. Warren, Chairman & CEO
South Carolina Electric & Gas Company

David H. Wiggs Jr.
David H. Wiggs, Jr., President & COO
El Paso Electric Company

Mr. STALLINGS. Thank you, Dr. High. Mr. Will?

STATEMENT OF ROBERT P. WILL, WASHINGTON REPRESENTATIVE, METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA, WASHINGTON, DC

Mr. WILL. Thank you, Mr. Chairman, I appreciate the opportunity to be here this morning to support funding for the HTGR Program at DOE.

I am Robert Will, I am the Washington representative for the Metropolitan Water District of Southern California. As some of you may be aware, we are a large public agency located in Southern California currently supplying water to a population in excess of 13 million people.

As a result of some recent population studies done by the State here last year, we have discovered that just since I testified here a year ago, our population is about a half million people or persons larger than we had anticipated it to be. And we expect that population growth to increase by 20 percent just over the next 12 years.

At the current time, our water resources, in addition to whatever local supplies we have, come from the Colorado River and from 600 miles away in northern California, and the potential for developing additional surface water supplies for our area is becoming much more difficult and we are spending a great deal of time looking at a variety of alternatives to maintain a water supply for this population.

Just to give you an idea of growth that we have of the 10 fastest-growing counties in the United States in terms of total numbers, our service area includes five of those counties. Our population pressures are rather incredible and are greater than we had anticipated them to be.

One of the most attractive things that we have been looking at has been desalination of water, and we have tried to put together plants in the past. The costs got out of hand and those projects had to be abandoned, but the gas-cooled reactor is starting to look much more attractive to us today. And with the work that General Atomics has done, with the work that DOE has done and some of the other groups of utilities, it looks like it's moving towards a position where it is time to start a prototype.

And therefore, just in the past month, the Board of Directors of Metropolitan has approved a study to look at a combination MHTGR cogeneration/desalting plant that would be located somewhere on the coastline of southern California. The safety features make it attractive for being close to major population centers and the ocean makes it easy to find the water to desalt. It's an effort that we think is going to be essential when we look past the turn of the century for meeting our water needs.

This feasibility study which my Board of Directors approved would require that MWD itself put up $150,000 in cash and $150,000 in staff time; DOE would contribute $150,000 to this study and GCRA would put up about $150,000 in staff time also. We are looking at a total study cost of in the neighborhood of $600,000.

The study itself is broken down into a number of tasks looking at this potential. The first task would be a review of the physical requirements of this kind of a project, a general configuration of the project, and in addition of course licensing and other requirements that we would have. The study would look at the economics of the plant, both from the standpoint of energy production and water production.

The physical design of the plant would be reviewed, we would get some kind of an idea specifically of what kind of equipment we are looking at. Much of the technology other than the reactor itself is fairly well established, including the distillation process itself, and so there is an opportunity here to move fairly rapidly in putting together this kind of data.

The study would also include a site survey of possible locations somewhere within our service area. Institutional arrangements would be reviewed, what is the possible ownership, operational requirements of a plant of this kind, what kind of a consortium we would be put together as far as this first project. And then assuming that these studies indicate that this kind of a project is viable, then the study would proceed to lay out a project plan for us.

We believe that costs are going to look attractive, certainly from the standpoint of water, and we think the potential is there with a cogeneration type plant to have a substantial benefit for our people, not only from an energy standpoint but from a water supply standpoint.

So basically, that is why my Board of Directors supports rather vigorously continued funding of this program at DOE, and we ask that you give very serious consideration to it. Thank you.

[The prepared statement of Mr. Will follows:]

TESTIMONY OF
METROPOLITAN WATER DISTRICT
OF SOUTHERN CALIFORNIA
ON
FY 1989 DEPARTMENT OF ENERGY BUDGET REQUEST
HIGH TEMPERATURE GAS-COOLED REACTOR PROGRAM
TO THE
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

March 17, 1988

The Metropolitan Water District of Southern California's a public agency serving supplemental water to about 13.7 million people in the coastal plain of Southern California from sources in Northern California and the Colorado River. This number is expected to grow to 16.4 million by the turn of the century, a 20% increase in just 12 years. Obviously, the question of fresh water supply for the future is of vital interest to MWD and our residential and industrial users.

To meet these expanding water supply needs, our staff continuously examines all possible sources such as increased water conservation practices, waste water reclamation, additional remote surface supplies, purchases from

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Presented by Robert P. Will, Washington Representative other water right holders and, of course, desalination of seawater.

In 1987, our Board of Directors established an Ad Hoc Committee on Energy and Desalination and that committee has been intensively evaluating the viability of a nuclear-based cogeneration plant for electrical generation and desalination. From what we have learned, such cogeneration plants may well be an attractive option to Metropolitan for much needed future additions to our water supply inventory.

Our first work toward nuclear-based cogeneration began in the mid-1950s, but never came to fruition. The project, to have been located on an off-shore island adjacent to Huntington Beach, had progressed well into the preliminary design and property acquisition stages when it was shelved due to unfavorable energy markets which made it uneconomical. Until last year, our efforts have been limited to monitoring advances that have been made in nuclear and desalting technologies. We have participated in the Technical Advisory Committee of Gas-Cooled Reactor Associates and have worked directly with GA Technologies of San Diego on application studies.

MWD supports the development of MHTGR as an attractive option for large-scale desalination through cogeneration. We recognize that cogeneration is the most economical method of large-scale seawater desalination. This is because the desalination process utilizes a large fraction of the heat that would otherwise be rejected as waste heat by the electricity producing portion of the plant. We recognize that any steam electric plant could be considered for cogeneration desalination. At the same time we are aware of studies by the Department of Energy, the Electric Power Research Institute and others, which show that the significantly lower fuel costs for nuclear power results in lower overall power costs. Furthermore, the economic advantage of nuclear should grow if other fuel options experience scarcity escalation or increasingly severe environmental restrictions. Clearly, the plan for long-term water supplies must be based on technology with a stable future.

We consider the MHTGR an important nuclear option for several significant reasons. The first is the attribute of inherent safety. This is an essential quality for cogeneration desalination because the best location for such a plant is as close to the end user as possible, i.e., near the population centers. The aspect of inherent safety will be essential to gain the necessary acceptance of our customers for siting a plant.

The second reason for citing the attractiveness of the MHTGR is the "modular" design. Capacity can be added as required in small increments as the demand for electric power and water increase. This allows us considerable flexibility in planning for future needs and enables us to respond quicker to changes in planned additions. Furthermore, the required financial commitment can be distributed more evenly over time. This contrasts with large plant additions which require huge infusions of capital at infrequent intervals.

Finally, we are impressed by the fact that the product specifications and economic parameters of an MHTGR cogeneration system match the needs of our district. We believe the basic "cogeneration unit" would logically consist of two 350-MWt reactor modules coupled to a steam power conversion system equipped with a backpressure turbine. The heat rejected to the condenser would be the heat source for the desalination system. This basic MHTGR cogeneration system would have a net electrical output of 221 MWe and could produce as much as 75 million gallons per day (85,000 acre-feet/year) of fresh water from seawater. Based on present consumption patterns in Southern California, this would be adequate to meet the fresh water needs of over 350,000 people. An MHTGR desalination plant consisting of four cogeneration units would satisfy nearly half of the required supply additions to meet our population growth by the turn of the century.

On February 9, 1988, MWD's Board of Directors approved funding for a study to examine in more detail the feasibility of constructing a MHTGR Cogeneration/Desalination plant. Metropolitan will provide $150,000 and will contribute another $150,00 in staff time to support this study. Additionally, DOE will provide $150,000 and GCRA will provide approximately that level of support in staff time. This study's prime contractor is General Atomics with Bechtal providing subcontractor support and they are also contributing resources to this study. The total worth of the study will be in excess of $600,000. The study will examine the potential for a MHTGR Cogeneration/Desalination plant through six tasks as follows:

1. Project Requirements -- A set of requirements will be specified for the design of the nuclear, electric generating, and desalination portions of the plant. These requirements will cover scope of supply, design configuration, operations, product water quality, safety and licensing. Requirements for site evaluations and a set of economic guidelines will be specified.
2. Economics -- A complete cost estimate will be prepared. This estimate will include all capital, operating, and maintenance costs. A set of levelized product cost evaluations will be performed which take into account the plant life, cost of money, taxes, inflation, and decommissioning.

The results will be projections of the break-even levelized water price as a function of electric power sales price.

3. Plant Design -- The MHTGR plant design will utilize the reactor module as designed for the DOE program without modification. Therefore, the bulk of the design effort will concentrate on modifications to the power conversion system to accommodate a back-pressure turbine cycle and the design of the desalination plant.
4. Site Survey -- Sites will be evaluated based on the suitability for a nuclear plant, access for grid tie-ins, accessability for water system tie-ins, sea water access, jurisdictions of local, state, and federal regulatory bodies, and potential public and political issues.
5. Institutional Issues -- Scenarios will be proposed for potential participation including ownership, supply, and operation. The adequacy of present nuclear, water, and electric power regulations will be assessed. Any need for new regulations will also be addressed.
6. Project Plan -- If the results of Tasks 1 through 5 indicate the project is viable, a summary project plan will be prepared. The plan will consist of a

description of the design, licensing, and construction. A schedule for initiating and conducting each phase of the work along with a proposed organizational chart will be prepared.

The overall product cost associated with a cogeneration plant is generally expressed in terms of the cost of electric power and the cost of water. In the case of a two-unit MHTGR cogeneration plant, the "break-even" product water price appears to be approximately $200 per acre-foot if the electric power is sold at 5.7 cents per kilowatt-hour. If electric power is sold at 6.8 cents per kilowatt-hour, the "break-even" price for water would be essentially zero.

The study will more accurately determine the cost of the product water and electricity. It should be completed by this fall, and if the results are favorable, both technically and economically, it will serve as a decision document to decide whether to proceed further with the project. If all studies and the design progress smoothly, it is possible that a facility could be built around the turn of the century.

We believe that the MHTGR development program should move forward as it provides another alternative for our long-range planning program. Funding should be at levels which will demonstrate the technology if it is to be an option for water supply in the future. Its costs, efficiency and safety must be shown to be acceptable as an energy source.

As a further indicator of our support for the continued development of the MHTGR, Mr. Les Balmer, Chairman of our Board of Directors, is a signatory to the "Joint Utilities' Statement on the MHTGR Program" submitted to various congressional committees and subcommittees.

Thank you for the opportunity to present this statement.

PANEL 1: DISCUSSION

Mr. **Stallings.** Thank you, Mr. Will. Let me pose a couple of questions and then I will defer to my colleagues here.

Mr. Blue, you state in your testimony that the core of the MHTGR cannot melt and thus cannot release radionuclides. Those are categorical statements and there must be some qualifications to them. What are they?

Mr. **Blue.** There aren't any. And the simple reason there aren't any is that the laws of physics guarantee that the temperature at which the fuel particles could melt simply can't be reached. Heat would be radiated out of the pressure vessel, and if nothing else, into the earth surrounding the reactor at a rate which is determined by easily-defined physics formulas and equations. The heat cannot build to the point of 1800 degrees Centigrade where you can start to have fuel particle failure.

That's why it's so easy to look at the safety. If you lose all the coolant, if the coolant isn't only not circulating, it's not even there, you still can't get to a point at which the fuel fails. That's where we need to be to have the kind of safety that Dr. Lidsky is talking about.

Mr. **Stallings.** How about the graphite fires that occurred at Chernobyl?

Mr. **Blue.** That's an interesting subject. It's much misunderstood I would have to say. There are long papers on the subject. In essence, it wasn't the graphite that was burning and causing the smoke at Chernobyl, for the simple reason that if graphite oxidizes, it gives off carbon monoxide which we all know is invisible. What you saw in the plumes of smoke around Chernobyl was probably tar on the building roofs burning. It was anything but graphite. And further studies of Chernobyl have indicated that what was perceived as a glowing core may have in fact been a gantry that was fallen down in the middle of the core and there was heat obviously coming from the core but it was reaction heat, it was the heat of the core. But it wasn't the graphite burning.

There was some oxidation of graphite, but if anything, it is believed now that the graphite at Chernobyl probably mitigated the damage and the releases. In any event, it had no relationship to the cause of the failure. Graphite is a big, stable element; it does not go well with water, and of course we don't have water in our reactors, we have gas. We're not suggesting anything like the Chernobyl reactors. What we are suggesting is obviously the gas-cooled reactor with the graphite core as moderator in its most stable form. And I think empirically, anybody starting from scratch on a reactor would say these are the kinds of ingredients you want.

I recognize that we're going to be continually discussing and explaining the differences, but the differences are huge. It's almost a non sequitur to even put the two together.

Mr. **Stallings.** I believe you mentioned in your testimony enormous process heat applications for the MHTGR. The Germans are routinely operating their average HTGR at a 950 degree Centigrade steam temperature, which is, as we both know, essential for process heat applications. Since their technology is based on pebble-bed fuel, how do we know the U.S. prismatic fuel design can reach these temperatures?

Mr. Blue. We've already had two demonstration projects here; one, the Peach Bottom reactor, and the Fort St. Vrain reactor. And we have essentially all the same physical elements that the German reactors do, and we operate in virtually the same temperature area.

The key is the fuel particles, and you control the temperature up to essentially the same types of levels the Germans have.

Mr. Stallings. One final question, Mr. Blue. Is the Fort St. Vrain reactor considered a failure for the technology? And if not, why not, considering its poor operating records?

Mr. Blue. I would say it should be considered a considerable technical triumph. It is a commercial failure by any standard because it hasn't run reliably. The simple reason it hasn't run reliably is because it has a bad lubricant. It uses water for the circulator cooler bearings. Well, it doesn't take much to know that water is not as good a lubricant as oil. That was a serious design mistake made 20 years ago. Fort St. Vrain differs from 53 other gas reactors around the world that use oil-lubricated bearings and work just fine. In fact, our studies indicate that Fort St. Vrain would have had an availability factor of about 70 percent were it not for that one system. And 70 percent is quite respectable. The earlier test reactor had an 86 percent availability.

So taking a conservative approach to the circulator bearing problem, I don't think there's any question but what the things that Fort St. Vrain proved, which are the integrity of the fuel, the integrity of the moderator, the integrity of the fuel handling equipment, the control rod drives, the steam generator, all those things have worked and are working extremely well. It's just very sad that one mechanical system can have given the technology, I have to admit, a bad reputation.

But in the ModularHTGR, in the wisdom of this Committee in telling us to go this route, we have such a conservative design that that problem will be forever behind us.

Mr. Stallings. Thank you, Mr. Blue. Dr. High, you mentioned in your testimony a phased-commitment approach to releasing DOE funds for the MHTGR program. Can you explain in more detail how this system would work?

Dr. High. Well, the way we've suggested the way this program would work would be to keep a reasonable level for the technology development and give the program the opportunity to develop the outside funding necessary to go ahead with the prototype. So that the phased approach would look at things like the licenseability question, and when that was finished you'd make a go/no-go decision based on the amount of outside funding you might have outside the Federal Government.

We think an approach like that does two things. It tries to stabilize the development effort, and secondly, it probably gives us the opportunity to make good use of whatever funds are available for that program. So it's that kind of an approach that we've suggested and in fact have tried to carry out on the gas-cooled reactor.

Mr. Stallings. Also, last year you testified that you need $45 million for Fiscal Year 1989. Of course, that was a year ago and that may explain it, but could you tell us for the record why you changed your recommendation this year to $35 million?

Dr. HIGH. I think in reality, based on the progress to date through FY 1988, probably $45 million would be a little optimistic on what you could really use effectively. There is some critical mass of expenditure necessary to keep the technology development to the point that you can do the licensing qualification and verification, and we think $35 million will do that for us. $45 million obviously would accelerate that some, but that's the reason we made the recommendation we did, considering the budget constraints that we know exist.

Mr. STALLINGS. Thank you, Dr. High. Mr. Will, I applaud your firm's commitment to this next-generation technology. California could be a leader in yet another area, pioneering inherently-safe nuclear technology in a cogeneration setting.

Last year, you admitted in your testimony to this Committee that public acceptance of nuclear technology, I quote, "is a very serious problem as far as California is concerned." Have you made any progress on this front concerning your project?

Mr. WILL. We have not dealt directly with an issue of this kind. We have still been reviewing the technology and trying to identify the project itself. We appreciate that public acceptance is going to be a serious problem, and we feel that hopefully by the time a project of this character is ready to be put together that there will be a great comfort level for siting of any type of nuclear plant. And particularly, HTGR, which as Mr. Blue has indicated, certainly has a high safety factor.

Mr. STALLINGS. I suggest that since this project is such a new direction for nuclear technology, you should also seek funding and support from the state of California. It fits California's pioneering reputation of striking off in unique policy directions. Have you any comment on this?

Mr. WILL. I think that the State may well come into a project of this kind sometime in the future, but I think that Metropolitan Water District itself at the present time is committed to undertaking some of the work that's necessary to help in this development now. The State itself has not funded a great deal of research in this area as far as I know.

Mr. STALLINGS. Is the MHTGR cogeneration project of which you speak viable without Federal support?

Mr. WILL. I'm sorry, I would not be able to advise you of that at this time. I think that the research itself on the gas-cooled reactor must be funded by the Federal Government at this time. The balance of the project, the use of the generation equipment, the distillation equipment, is probably almost a shelf item and would not require federal support.

Mr. STALLINGS. Thank you. Mr. Morrison?

Mr. MORRISON. Gentlemen, one of the things that we have seen through this hearing process, which is always an educational experience for I think all of us on the Subcommittee, there seems to be a fairly consistent pattern of support for the light water reactor improved design for potential orders in the mid-1990's at some point, and then advanced technology of one type or the other, either liquid metal reactors or the high temperature gas-cooled reactors coming somewhat later. Since you obviously are enthusiasts for one of those new technologies, do you want to argue with this process which DOE seems to be following and most of the industry seems to be supporting?

Mr. BLUE. I would argue with it. I think that we've seen that the political consensus isn't there for doing a lot of water reactors at this point. In fact, there are a couple of water reactors that are finished that we'd like to operate that aren't operating. When you see that political consensus, you have to suggest or at least ask the question if there isn't something wrong with the basic concept.

Now, I stated earlier I happen to believe that water reactors are safe, but we also know they're terribly expensive, that they take a long time to build, that a 1,000-megawatt package of power may be too much for some areas to digest.

By contrast, at 140 MWe per module, we have a bite-sized version if you will that has these Level 1 safety characteristics that people could understand. And I think if they really focus on the fact that these reactors simply cannot melt down, and there are ways that you can demonstrate this to people, then I think they would much more rapidly choose this technology.

We are ready to build this technology. It has been demonstrated in this country, it's been demonstrated in Europe, and it's ready to be built. We don't need to wait past 1995 or the turn of the century. We can build a project right now probably as rapidly as you could build an advanced water reactor.

Mr. MORRISON. But no one has chosen to do that.

Mr. BLUE. No one has chosen to build a water reactor, either.

Mr. MORRISON. I think we are all convinced of the fact that the advanced design reactors are inherently safe, and have you tested any of that as far as public attitude is concerned? Being a strong nuclear advocate, I've always been frustrated by the fact that we had a lot of things to share with people but they weren't buy it. Are we going to be able to sell them on the inherent safety, particularly when you look at HTGR and some of our discussions yesterday with NRC about the need for emergency evacuation plans, whether you need those or not; whether you need containment or not. I think we've got some selling to do.

Mr. BLUE. I wouldn't diminish that at all. I have to admit that my ultimate objective is to get Jane Fonda to endorse this technology, but I'd have to admit we are quite a ways to that yet.

But in fact, the Audubon Society, for example, has endorsed two technologies for electricity; one is solar, I think we would all endorse that, the other is the HTGR. There are other environmental organizations that say we may be anti-nuke for whatever reason, but if you must have nuke then HTGR has it all over the others, and we'd like to see that.

When the Metropolitan Water District, which comprises many very sensible people but I can only conclude when you get over 50 Californians together there are some crazies in the middle of that, also—I think they voted 45 to 7 in favor of this proposal. That's pretty strong, and it does indicate that people are willing to listen. And we have a very strong story to tell.

It takes some more selling, I wouldn't diminish that at all, but we have the ingredients to sell. We have the ingredients that people want to see. They don't want to see environmental degradation—we are the cleanest, most environmentally compatible source of power there is. There are no emissions of CO_2. Our radiation is about one-one-hundredth for the workers of what you expect from a water reactor. Those are the kinds of things that I think will be a lot of fun to sell because people can understand that, and that's what they want.

Mr. MORRISON. We would agree with that. I think all of us want to be partners as we move ahead with what is the right answer to the energy opportunities you described in your opening statements.

What—maybe either Dr. High or Mr. Will—what do you sense NRC is going to do? Are they going to say we don't need emergency evacuation plans because of the inherent safety, or we don't need containment because there's nothing to release?

Dr. HIGH. Let me speak to that. I think it's very hard to guess what the NRC will do. We've been playing that guessing game now for about two years on the reactors we have. But I think, coming back to your previous question, I think it's a very strong sell job that we need to convince them. And if we can convince the public, I think the NRC will also see the technology as we do. I think given their charter and life and their role to protect the public, they're going to ask those tough questions and will continue to ask those until we can, in fact, convince them otherwise. I think we can do that.

I've seen some movement in the NRC of accepting some of the passive safety features that we've spoken to, in meetings with those people. That's not going to be an easy sale, either. I believe the NRC technical people can help us in that regard; I think they see the passive safety features. But I would be the first to admit to you that is a tough go, too.

Mr. WILL. I would have to defer to my colleagues here, Mr. Morrison. We have not done a great deal of work on the licensing side of this program.

Mr. MORRISON. I guess maybe for you the most significant question is, "Can you sell this in California?"

Mr. WILL. There's no question that that is going to be tough, but as I mentioned last year we've sited three reactors in California, major light water plants, and despite a great deal of opposition, certainly two of them are working very effectively today. One is down for other reasons than public perception. So I think the potential is there to convince the public.

Mr. MORRISON. I sense, as I have followed the scene in California and here in the northeastern United States, that you have been able to maintain a little better support from local governmental units. Is that an accurate statement?

Mr. WILL. Yes, I think that is correct. The project at Rancho Seco, now that they're having so much trouble with, I think is not primarily a public fear of nuclear but more a cost problem. And the local governments, in looking for the resources that they need to continue their development, have generally been supportive.

Mr. MORRISON. Thank you, Mr. Chairman.

Mr. STALLINGS. Mr. Fawell?

Mr. FAWELL. Thank you, Mr. Chairman. My thoughts are somewhat along the same lines as the previous questions from Congressman Morrison. Mr. Blue, you made the statement that we have the ModularHTGR, as I understand it, ready to build, we don't have to wait. We can build it as rapidly as possible you indicated, but as has been pointed out, there is a problem in regard that the public is not buying that. Apparently, DOE is lessening its financial commitment, or indicating that there should be a lessening of its financial commitment. And environmentalists aren't—they aren't here; they never seem to show up at the Energy Science hearings, which has always bothered me. And I've mentioned in many a speech back home to the people who are so concerned about the environment, why aren't you taking an interest in the many, various Energy Science programs.

Is there any concerted effort to really get the environmentalists concerned about this, and to ask the question in terms of cost-effectiveness? Maybe we're at it right now, maybe it is cost-effective. Considering all the arguments to the contrary when you consider all the disease and death that comes from continuing burning fossil fuels and burning holes in the biosphere and the atmosphere and dropping all of the emissions, sulfates and phosphates and so forth and so on on our soils and in our lakes and in our food and so forth and so on.

I don't think there's any real effort by those who advocate new energy sciences to do much in the field of advertising their good works, and the potential of their good works. Do you have some comments on that?

Mr. Blue. I would have to agree with you. There is, of course, an advertising program that attempts to explain nuclear and the desirability, but I would characterize it as a lack of urgency. Unfortunately, usually we have spawned urgent problems and we don't respond until we have them. And with oil at $15 a barrel and the trend perhaps downward, people can say, "Energy problem? What energy problem?"

The problem is that they are not thinking ten years down the road, the ten years that it takes to put a new plant in operation. They're not looking at the projections where if we're going to have economic growth, we are also going to have to have more electricity. Well, the alternative, of course, is to come up to that critical problem time in the mid-1990's and simply burn more oil and gas.

Mr. Fawell. Or perhaps with superconductivity, for instance, you could store it and maybe looking and assuming well, we're going to be able to meet those problems; we're going to have more generation of electricity as we look at such concepts as superconductivity and being able to store and friction-free transfer of electrical energy and things of that sort.

Mr. Blue. Those things are all in the technological basket and the sooner they come, the better. A lot of good work is being done on that. I wouldn't project that they're going to solve our problems by that timeframe.

Mr. Fawell. But commercial entities aren't buying this, either. And DOE seems to be looking more at the liquid metal reactor program as their main emphasis. Somehow, the message isn't getting out, isn't selling.

Mr. Blue. Two things. First of all, in GCRA you have 35 percent of the electrical-generating capacity utilities represented in this group, and they are contributing money to the cause, they are attempting to keep attention focused on it, and they're saying, "Fellows, there is a problem coming down the road and this is the best solution that we can see". That's not all the utilities but it's a very substantial part of the utilities.

Then you have the big company, Siemens, which has a world perspective if anybody does. They see what's happening in the world. We don't have an urgent problem right here in this United States this year, or perhaps even for the rest of this decade, but we do in the next decade. The need in the world is right now, and Siemens has identified that and they have recognized it. They are one of the leading builders of water reactors in the world; they have identified the need for high temperature gas modules to satisfy the people on some of the safety issues but also to have something in packages that are small enough to digest, and which don't require the tremendous infrastructure in a developing country that the more complicated reactors do.

So I have to say that we're not there yet in terms of the sense of urgency, but I can see just in the past year a shifting to be willing to talk about this and starting to recognize that yes, we are headed toward a problem and now's the time to take measures to avoid it.

Mr. FAWELL. Just one other thought. It would certainly seem to me, after Chernobyl, that we should recognize that it's in our best interest even if we don't accept it in this country to perhaps get other countries to accept it because the prevailing wind systems are such that what they build out there is still important to us.

Mr. BLUE. Absolutely. And actually, the Soviets are among those who recognize it, and the Soviets are going to be visiting GA. We've had extensive discussions with the Chinese. The Italians have had their referendum and said no more water reactors, and we're very interested in gas reactors. So there is this feeling I'll say in many parts of the world that we have to have a new look and gas reactors are the best thing we can see at this point.

Mr. FAWELL. One other thought. I mentioned DOE—I don't know if it's correct to say that their ardor is cooling a bit in regard to the HTGR; maybe on the basis that, "Hey, it's there now; it's going to be picked up by commercial interests or not." The liquid metal reactor is not as advanced; a lot of long-term basic research is necessary. Why do you see a lessening of—considering the fact that we don't have much extra money and we have to prioritize. They seemingly are indicating a prioritization toward liquid metal reactors.

Mr. BLUE. Well, first of all, I would have to say that foresight in this matter must go to you people; you're the people who turned on the ModularHTGR program, you're the people who have sustained it. We know that in the Department of Energy their primary experience is in the water field, and perhaps secondarily in the liquid metal field because of all the action on the breeder program. So there is a big body of knowledge and, I dare say, prejudice.

But truly, I read the Department of Energy a little bit differently this year than I did last. The original proposal last year was, if I recall correctly, for $5 million of funding, and this year of course the recommendation is $7.7 million. So that might be statistically not a big difference but the Department of Energy is beginning to take this technology, I would say, very seriously. And little by little, as people become familiar with it, they find out that it has the characteristics that any reasonable person who is looking at this problem seriously wants.

So I would say that at least in the past year, the Department of Energy if anything—they bottomed out in their feeling about HTGR and it's definitely on the uptrend.

Mr. **FAWELL**. Thank you.

Mr. **STALLINGS**. Mr. Hochbrueckner?

Mr. **HOCHBRUECKNER**. Thank you, Mr. Chairman. Actually, I don't have any questions but I would like to make a statement relative to this technology. Certainly I accept as the world has, that we have 103 operating nuclear plants in the United States and certainly quite a few still in the pipeline. As someone who comes from a 25-year background in aerospace engineering and who happens to represent eastern Long Island where the Shoreham nuclear power plant is located, certainly it is no secret that I am doing my best to stop the opening of Shoreham. There are a variety of reasons for that.

There is a great concern about the safety and the construction of that particular plant, certainly it was built in the wrong place and we are very concerned about that. It is also very clear that if that plant is allowed to open, we will have the highest rates of any utility in the United States. That is certainly something that we are trying to avoid.

That is a major problem for me personally. I think it is time to face reality. As far as I can tell, and I think it should be abundantly clear to most people, that it is over for today's style of nuclear reactor. There have been no new orders for plants since 1978. They are very expensive. The capital costs are outrageous and people fear them. The net result is that today's technology of boiling water reactors, it is over. If fission is going to have a future in the United States, you need to get into technologies like high temperature gas reactors.

I think this particular approach offers one of the best opportunities for fission to continue, if it is going to continue. If new fission plants are going to be built, they have to bring with them the reality and the perception that they are absolutely safe and cannot have meltdowns. Any technology that anyone tries to promote that does not have the reality and the perception that a meltdown cannot happen is not going to happen. People are not going to stand for it.

I would hope that the Congress would recognize the message from the people and that message is it has to be safe, absolutely safe. If there is any technology anybody is promoting along the lines of fission that does not fit into that category, I think you are wasting your time. You better realize that. It is over for today's style of nuclear power on the fission side.

Fusion, we have great hopes for. Perhaps this approach to fission, other approaches that bring the reality and perception of absolute safety have room in the future. Those 103 plants, when it is over for them, it is over. That's it. I will certainly continue to do my best to stop and prevent the opening of Shoreham. That's today's reality. We need to recognize it. We should invest appropriately for the future, if there is going to be any future for fission at all. This seems to be one of the better technologies to pursue.

Thank you, Mr. Chairman.

Mr. STALLINGS. Thank you, Mr. Hochbrueckner.

Gentlemen, we appreciate your testimony and your responses. You have been very helpful. I am sure what you have had to say will have a great impact on this Committee's deliberation.

[Questions and answers for the record for Mr. Blue and Dr. High follow:]

GENERAL ATOMICS

May 11, 1988

The Honorable Marilyn Lloyd
Chairman, Subcommittee on Energy
Research & Development
Rayburn House Office Bldg., B-374
Washington, D.C. 20505

Attention: Lottie McCaw-Daniels

Dear Madame Chairman:

Enclosed are answers to the questions which followed my March 17th testimony. Thank you for the opportunity to provide this additional information to the Subcommittee concerning the Modular High Temperature Gas-Cooled Reactor.

I believe the continuing support of your Subcommittee and other visionaries in the Congress will be rewarded with a safe, environmentally benign energy source for the twenty-first century. Such energy sources are indeed crucial for our domestic economic activities and will provide us with a highly valuable export technology.

Sincerely,

Linden Blue
Vice Chairman

Enclosures

10955 JOHN JAY HOPKINS DRIVE PO BOX 85608 SAN DIEGO CALIFORNIA 92138-5608 (619) 455-3000

5/11/88

Question 1.

The HTGR seems to have many attractive safety features (core won't melt, fuel won't release radioactivity), and yet there is only one HTGR plant in this nation. How can the utility companies be persuaded to buy more HTGRs?

Answer

A large number of U.S. utilities actively participate in the Modular HTGR (MHTGR) program and have indicated an interest in purchasing such facilities once the economics and operational advantages have been verified. The program therefore faces a very difficult chicken-and-egg problem regarding sale/construction of the initial, four module MHTGR facility. An aggressive industry and government collaboration is required on the initial facility. I believe that once the initial facility is operating (or at least well underway), the utilities will, of their own volition, purchase more MHTGRs.

Potential MHTGR vendors and suppliers, including General Atomics and Siemens/Interatom, have begun a private initiative which will establish a framework under which users, suppliers and energy development organizations can combine their capabilities to go forward with the initial facility. The fundamental premise of this initiative is that each participant in the project must accept the financial responsibility and risk for those activities consistent with the charter of their organization or for those activities over which they have the most control. In practice this will mean:

- Suppliers/vendors will accept the responsibility and risk (generally in the form of fixed price contracts) for the engineering, construction and all other major components and services including initial plant performance and warranties.
- The Facility Purchaser will pay a competitive price based on the commercial value of the facility and will accept responsibility for operation, electrical production and sales beyond the warranties provided by the vendor.
- Governmental Energy Development Agencies must accept the responsibility for a large share of the first-of-a-kind (FOAK) technology, development, construction and fabrication costs, as well as indemnify the participants for the licensing/political risks (possibly through a loan guarantee) which are outside the purview of the private sector.
- Other Energy Development Agencies, Vendors and other Financial Parties will accept responsibility for a share of the FOAK components and systems associated with their interest.

Agreement on this basic philosophy between all participants will permit the vendors and purchaser to secure financing for the commercial value of the initial facility and to proceed with procurement of long lead time components. Site civil work will commence upon receipt of the construction permit allowing private industry to assume responsibility for the majority of costs and for the commercial deployment of subsequent plants.

We believe that a utility company can be persuaded to buy the first MHTGR by the presentation of an offer of the nature described. Subsequent decisions to buy will be encouraged by the licensing and political acceptability but driven by the operational and economic attractiveness.

The need for an initial facility to verify the economy and operability of the MHTGR could also be met by selection and construction of the MHTGR as the New Production Reactor (NPR) to be built in the 1990's. Selection of the MHTGR-NPR would therefore have two major benefits:

1) The cost of tritium (after electrical revenues) would be dramatically less than from a non-electricity producing alternative.

2) The development and FOAK costs for the NPR would prepare the MHTGR for commercial deployment.

While it may be possible to characterize the selection of the MHTGR-NPR as more technically challenging than to update the non-electricity producing production technology of forty years ago, the safety, commercial and economic benefits of MHTGR development are well worth the effort.

Question 2.

You favor the idea of exporting HTGRs to developing countries. How competitive is the market now?

Answer

The export market for electrical generating stations and component equipment for developing countries is, and will remain, highly competitive. The MHTGR addresses this market's needs for simple, safe, economically competitive, non-fossil electrical generation to fuel the rapid economic development which these countries plan to achieve. In recognition of these facts, the MHTGR (at ~140 MWe per module) is also an attractive size for smaller electrical grids and can meet local needs in isolated areas. A number of industrial organizations in several countries are positioning themselves to be suppliers to future HTGR projects in the developing countries. While the U.S. is currently a front-runner in MHTGR technology, we must have an initial facility operating successfully in the late 1990's if we hope to participate in the multi-billion dollar annual MHTGR export market expected in the first decade of the twenty-first century. Such a market position would create domestic jobs for the fabrication of the higher technology components, i.e., fuel, steam generators, pressure vessels, circulators, turbines, etc.; help improve our future balance of payments; and maintain U.S. influence to help minimize the risk of weapons proliferation in the developing countries.

The developing countries are exhibiting unusual interest in the MHTGR because:

1) The simplicity and inherent safety make it particularly attractive in a country with limited numbers of highly trained personnel.

2) The 140 MWe module size allows them to add capacity as needed and does not require massive initial investment to be cost competitive.

3) Future power costs will be relatively insensitive to fuel costs and are less subject to the short-term interruption and price hikes seen in oil and natural gas.

4) The conventional (modern fossil conditions) nature of the energy conversion area (principally the turbine generator) has the potential of being built domestically by the developing country, thereby reducing the hard currency requirements for the project.

5) Reasonable size power plants can be fueled in isolated providences without large investments for pipelines, rail systems, or roads normally required for fossil-fired facilities.

These countries are also aware that the high outlet temperature capability will permit it to provide industrial process heat for steel making, oil recovery, coal gasification and hydrogen production. As such, the MHTGR could be an important component of a broad based energy program for a developing country. Considering the electrical generation alone, the potential MHTGR annual export market can conservatively be estimated as tens of gigawatts (~$50 billion capital cost) in the first decades of the twenty-first century.

This potential HTGR export market has drawn the interest of suppliers in Germany, France and Japan, as well as the U.S. The most aggressive marketing is now being done by reactor vendors from the Federal Republic of Germany who have offices and representatives in several developing countries and have initiated preliminary studies in both China and Russia. The German vendors also have provided design descriptions and budgetary quotes for other countries. The French and Japanese interest in the HTGR export market is (apparently) currently limited to being a supplier of large components for systems sold by German or U.S. vendors. At the same time, Japan has an active HTGR program directed primarily at higher temperature industrial process heat applications. The Japanese program is now developing a prototype with construction scheduled in the early 1990's. As previously noted, the Soviet Union is working with the German MHTGR vendors and have plans for a 100 MWe MHTGR and a ~400 MWe HTGR, also to be built in the 1990's. The Soviets expect to supply many of the major components for this facility and may also be considering the export of similar items as the market develops.

The magnitude and competition for the HTGR export market appear to be increasing as the international vendors for light water reactors (LWRs) are showing increasing concern about exporting these large, complex systems to the developing countries. Because of the lack of trained maintenance and operations personnel in many developing countries and the recognition that a major incident with one of their foreign facilities will strongly impact their domestic market, several international LWR vendors have, to a large degree, withdrawn for this market. This withdrawal is expected to increase the future market share for the HTGR in the export market.

While the U.S. enjoys a strong HTGR technological position, our access to the export market will be determined by whether we have a licensed and operating module. With a substantial market expected in the 1995 to 2010 time frame, it is crucial that the U.S. proceed with the initial facility described in the answer to the previous question. Both the domestic and export MHTGR markets depend on the successful construction and operation of an initial facility.

Question 3.

Would NRC certification of the modular HTGR design eliminate most of the licensing uncertainties you mentioned? What are the major technical issues which remain to be solved?

Answer

NRC certification of the MHTGR design would indeed eliminate the majority of the licensing uncertainties. We believe that such a certification would serve to stabilize the regulatory climate and permit the vendors to take the standardized module to the competitive market. We recognize and accept the need for site specific licensing considerations, but feel that a comprehensive review and certification of the technology, safety philosophy and implementing physical systems will allow the vendors and users to move ahead with subsequent commercial projects.

The technical issues which remain to be resolved are not fundamental to the MHTGR concept in that most are incremental in nature and are intended to improve performance, efficiency and operability. With the completion of the conceptual design, the remaining technical issues were reassessed and various lists were prepared to guide the technology and development programs.

The technology program being completed (to a large degree at Oak Ridge National Laboratory) focuses on the fuel, graphite and metals material characterization programs. While these studies are crucial to completing the regulatory data base and therefore to licensing, the existing data base is sufficient for the completion of the design with an extremely high confidence level. Although we may need to make modest improvements in fuel quality, extend the code temperature ranges for pressure vessels, and reduce the variability in graphite strength, this progress will be achieved by the completion of orderly programs already in place and do not require technological breakthroughs.

Similarly, there are several technical issues which will be resolved in the preliminary and final design which may slightly impact system size, configuration or equipment selection, but do not raise questions of feasibility. Among these issues are plant availability, gas mixing in the lower plenum, neutron shielding from the vessel top, and steam generator flow characteristics. Each of these issues will be resolved as that portion of the system proceeds through the detailed design process. The MHTGR program has been structured such that the major technical issues involving safety, licensability, operability, maintainability, and projected costs were resolved during the recently completed conceptual design. The remaining issues, while extremely important, are not fundamental in nature.

GCRA
GAS-COOLED REACTOR ASSOCIATES
10240 Sorrento Valley Rd., Ste. 300
San Diego, CA 92121-1605
(619) 455-9500

April 25, 1988

Subcommittee on Energy Research
and Development
B-374 Rayburn House Office Building
Washington, D.C. 20515

Attention: Lottie McCaw-Daniels

Dear Sirs:

On behalf of GCRA, the responses to your questions regarding the MHTGR Program are enclosed herein. If there are any additional questions, please don't hesitate to contact me.

Sincerely,

J.I. Meares for
Michael D. High, Director
Energy Demonstration and Technology
Tennessee Valley Authority

Enclosure

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

HEARING ON DOE FY-1989 AUTHORIZATION REQUEST FOR NUCLEAR FISSION

Republican Member Questions and Responses
for the Hearing of March 17, 1988 for
Dr. Michael D. High, GCRA

Q1. A phased approach to obtain private sector support for the advanced HTGR program seems to make good sense. Is there such a plan?

A1. The concept of a "phased" approach for conducting the HTGR Program, as well as the other advanced reactor programs, has been advocated for many years. Whereas such an approach has yet to be formalized and implemented, there are increasing elements of the approach being implemented informally. During the past year, there has been a call for input from various Congressional offices regarding a "legislative initiative for advanced reactor deployment". Our input has been built around the phased approach for conducting advanced reactor programs.

Q2. In your opinion has the advanced HTGR program been effectively managed so far? What is the impact if no more funding than that requested by the DOE is appropriated?

A2. Overall, we consider the HTGR Program to be managed effectively. Particular strong points in the management process include:

- A structured, top-down methodology, based upon systems engineering principles, has been established for management of design, licensing and technology development. The methodology starts with utility requirements and top-level regulatory requirements and applies functional analysis techniques to develop lower level requirements in conjunction with optimal design solutions. The positive results of this "requirements oriented" approach to design has been evident in utility reviews.

- A vendor team that has evolved that is working together to develop the nuclear island design as well as to support a Project initiative to commercialize the design. Plant level design integration and configuration management is managed by DOE through a Plant Design Control Office, staffed by seconded personnel from the major Program contractors and subcontractors.

- Program procedures and most operational plans are in place and maintained on a continuing basis. The conceptual design has been baselined and is subject to change control procedures.

- A structured requirements-based management approach for the technology development process is in place whereby the designer establishes the "Design Data Needs" that serve as the specifications for the technology programs. This approach avoids the technology development "sand-box" and the resultant cost burdens. Oak Ridge National Laboratory has been designated as the Lead Lab for the HTGR technology programs.

- Organized utility support and participation that establish utility requirements and represent the owner/operator in all levels of the program is in place through Gas-Cooled Reactor Associates.

Continuing efforts within the Management development process for the HTGR Program include:

- Establishment of an agreed-upon plan for the long-term design, licensing and technology development activities and the resultant costs.

- Establishment of an overall Management Plan that clarifies the roles, responsibilities and cost sharing arrangements among all the Program participants.

- Establishment of a comprehensive plan for international cooperation.

- Improved consistency and efficiency, particularly within DOE and the utilities, regarding their management roles and responsibilities for all the advanced reactor programs.

If only $7.7 million was appropriated by Congress for the HTGR Program in FY-1989, it would drastically derail the progress and momentum achieved to date. Technical program resources would be reduced to one-third the current level which would be insufficient to maintain the critical skill resources developed to date. Participation and support from the utilities, vendor participants and foreign countries would be reduced accordingly and prospects for an MHTGR commercial alternative would be seriously delayed and potentially lost.

PANEL 2: ADVANCED AND SPACE NUCLEAR REACTOR PROGRAMS

Our next panel of witnesses, also a very distinguished group, the first witness is from the District of our Chairman, Mrs. Lloyd. I am proud to introduce Dr. John Jones, Director of Reactor Programs at the Oak Ridge National Laboratory, one of the fine showcases of high technology research in the Government's laboratory system.

He will be accompanied at the table by the second and third witnesses that represent the General Electric Corporation and will explain the different elements of their company's work on space power and advanced reactors.

Mr. R.C. Berglund, Manager, Advanced Nuclear Technology at General Electric and Mr. James H. Frey, General Manager of the G.E. Aerospace Group. The third witness, Mr. John McDonald has taken ill and Mr. Robert E. Harris, Director of Energy Systems with Rockwell International, will present his testimony.

Gentlemen, welcome to the Subcommittee. Your entire written statements will be included in the record. Mr. Berglund, if you would begin and please summarize if you wish.

STATEMENT OF ROBERT C. BERGLUND, MANAGER, ADVANCED NUCLEAR TECHNOLOGY, GE NUCLEAR ENERGY, SAN JOSE, CA. ON BEHALF OF DR. BERTRAM WOLFE, VICE PRESIDENT AND GENERAL MANAGER, GE ELECTRIC

Mr. BERGLUND. My name is Robert Berglund. I am Manager of General Electric's Advanced Nuclear Technology. I am here today on behalf of Dr. Bertram Wolfe, our Vice President and General Manager for GE Nuclear Energy, who unfortunately had a long-standing conflicting commitment. I wish to submit his full testimony for the record and I would like to summarize some key points which we believe are relevant to the nuclear option and long term U.S. energy security.

In our view, nuclear power continues to be the only economic alternative to an excessive reliance on fossil fuels. None of the power sources available to the U.S. are without their problems, but on balance in our view, nuclear power can be the most economic, safest, most environmentally-benign source for the future.

It would be a tragedy for the U.S. which led the world's peaceful nuclear program and the development of economic nuclear energy, to be denied its future because of artificial barriers. It would be a failure of our Government and industrial systems if we are not able to develop the near-optimum technical and social arrangements for each of our power sources, so that when the need arose, our nation can choose the most suitable source for the time.

We are not suggesting we embark on a near-term program to build more nuclear plants but rather that we do the necessary work now to maintain nuclear power as a meaningful option for the future.

We believe there are two principal goals to be addressed in the DOE civilian reactor program, a focused program that assures U.S. energy security for the long-term and to this end, revival of the nuclear option.

A favorable solution to the short-term goal implies the use of light water reactors. The long-term goal can be satisfied with the liquid metal reactor technology which includes the breeder. The

LWR and LMR goals are complimentary and both should be pursued.

While there are many specific constraints to a viable U.S. nuclear option, the most significant are institutional factors beyond the control of the private sector. To be more specific, the existing U.S. regulatory practices and procedures controlling the environment for construction of nuclear plants makes their schedules too long, their cost too high, and their unpredictability too great. The product is not the issue. U.S. LWR designs are standard in Japan and France, are routinely constructed in four to five years by multiple utilities and multiple suppliers and they provide excellent operating performance and good economics.

General Electric supports the legislative reforms in the licensing of nuclear plants. We support one-step licensing, limits to backfitting and pre-approval of sites. To be successful, these reforms require standardized designs entailing very large investments before it is clear that the environment necessary for successful nuclear power deployment has returned.

U.S. reactor manufacturers have continued to make significant technological investments by working with overseas partners and customers where the environment for nuclear power is more favorable. These partners and their governments have recognized the value of this U.S. capability and maintained their long standing relationships in the development of advanced designs. We now have advanced light water reactor designs that can be adapted and deployed in the United States if we can solve the institutional constraints.

The LWR program proposed by DOE and approved by Congress is a major step to eliminating these constraints. Private industry alone cannot be expected to make such investments far in advance of potential use when faced with the high degree of uncertainty in the U.S. environment.

The Department of Energy's advanced light water reactor certification program provides the Government's demonstration of its resolve to re-establish the nuclear option in the United States. This is a Government role, not an industry role. This Government program in conjunction with the Electric Power Research Institute program and the advanced designs developed by industry can provide leadership and the technical basis necessary to achieve regulatory certification of the modern standard designs, certified designs that will help to effectively control the excessive costs and schedules now associated with U.S. nuclear plants.

In the case of GE's advanced boiling water reactor developed in Japan, we are encouraged by the response of the NRC at both staff and Commissioner levels.

We believe it will also be advantageous to increase the flexibility of the U.S. nuclear option and be able to economically deploy nuclear plants in increments of 500 to 600 megawatts. These designs, however, will have to benefit from enhanced features such as special safety characteristics to offset the dis-economies of scale affecting mid-sized systems.

To this end, DOE's development program initiated last year with Congressional support will provide the type of data necessary to assess how much the improved designs might proceed through an

NRC certification process. Again, we are encouraged by the progress to date and by NRC's new policy which is intended to improve the licensing environment and minimize complexity and uncertainty in the regulatory process for advanced nuclear power reactors.

EPRI has incorporated this program thrust into its advanced plans and is supporting its development based on the designs from reactor manufacturers such as GE. International interest is growing rapidly and we believe a real opportunity for worldwide collaboration exists.

The real promise of nuclear power is an unlimited energy supply through the liquid metal breeder. Even with a low breeding ratio, the LMR once fueled can continue to maintain its capability with essentially no new uranium supplies. Uranium is a finite resource. This has been the promise of LMR development from the early introduction of nuclear power and continues to be a goal for long term energy security.

The development and demonstration of an economic LMR design is an ongoing worldwide effort. Programs to date based on a series of large monolithic plants, such as the European SUPERPHENIX-I, have proven to lead to high-cost demonstration plants and uncertain future competitive economics.

The U.S. DOE advanced LMR conceptual design program carried out over the past three years shows real promise of major reductions in the cost of developing and demonstrating LMR's that can be competitive with future coal and advanced nuclear systems. The modular LMR approach such as GE's PRISM, when employed in a U.S. LMR program, promises to reduce the cost of a prototype demonstration to less than $1 billion rather than the multi-billion dollars associated with those of the large monolithic designs.

Additionally, this modular approach should be particularly attractive for the U.S. utility market since it will permit capacity additions in smaller, more flexible increments which reduce the initial investment commitment and risk and enhance the utilities' ability to meet uncertainty in future demand growth.

A key factor in the U.S. advanced LMR designs, such as PRISM, is the promise of the enhanced reactor protection that could increase public acceptance of nuclear power once demonstrated in a comprehensive test program and lead to a regulatory certification of a standardized plant.

The DOE is in the process of focusing its advanced LMR design program to achieve this potential. GE views this effort as a national endeavor and has therefore developed a broad-based team of experienced and complementary skills. This team is currently comprised of Westinghouse, Babcock & Wilcox, Burns & Roe, Bechtel, Stearns-Roger Division of United Engineers, Foster Wheeler and Byron Jackson. We have been developing a plan for an advanced LMR program based on PRISM and consistent with DOE program plans.

We believe this design focus coupled with continued support to key National Laboratory research and development, such as ETEC's steam generator and seismic isolation programs and Oak Ridge's advanced controls and shielding programs, will give the

U.S. a successful program at lowest cost and risk to the Government.

A key development requirement in a successful U.S. LMR program will be integration of the reactor development and demonstration with the metal fuel and fuel cycle development and demonstration program underway at Argonne National Laboratory known as IFR.

Metal fuel is currently the reference fuel for the PRISM concept. While PRISM can utilize either oxide or metal fuel without a change in reactor design, PRISM's use of the metal fuel offers a breakthrough potential for LMR economics. Additional ANL development tasks aimed at demonstrating the reliability of production fuel and completing the development of the integral fuel cycle should be oriented toward and combined with the reactor test program. It's logical that these two programs be integrated into a comprehensive effort as we believe they will convincingly demonstrate the self-protecting nature of the advanced LMR and the acceptability of fuel recycle.

While the above program features are primarily directed toward U.S. constraints and needs, their significance and innovation has been recognized by other nations and we believe it is possible to gain overseas participation in the U.S. advanced LMR program. The overseas development approach of large monolithic systems has proven to be extremely expensive and none has proven to be economically competitive. Therefore, we have found a growing international interest in our PRISM concept. A focused U.S. program aimed at an integrated reactor and fuel test could bring about major international participation.

In conclusion, we believe there are three basic elements for a successful future national nuclear program. First, in the near term, the nuclear option should be pursued through efforts leading to the regulatory certification of advanced LWR designs. This is a modest effort that can be completed in existing programs within three or four years.

Second, and the subject of other hearings, we must provide a basis for long-term international cooperation by putting in place positive agreements with our nuclear development allies such as Japan.

Finally, we must for the longer term proceed with focusing the demonstration of our advanced LMR concept and the IFR fuel cycle to ensure that these plants can be constructed and operated with user confidence and public acceptance.

We urge the Committee to support these design programs in the fiscal 1989 budget.

Thank you.

[The prepared statements of Mr. Berglund and Dr. Wolfe follow:]

ORAL STATEMENT OF

ROBERT C. BERGLUND
MANAGER, ADVANCE NUCLEAR TECHNOLOGY

GE NUCLEAR ENERGY

ON

CIVILIAN REACTOR PROGRAMS

BEFORE THE

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
HOUSE SCIENCE, SPACE AND TECHNOLOGY COMMITTEE

MARCH 17, 1988

MY NAME IS ROBERT BERGLUND AND I AM MANAGER OF GENERAL ELECTRIC'S ADVANCE NUCLEAR TECHNOLOGY. I AM HERE TODAY ON BEHALF OF DR. BERTRAM WOLFE, VICE PRESIDENT AND GENERAL MANAGER FOR GE NUCLEAR ENERGY, WHO UNFORTUNATELY HAD A LONG STANDING CONFLICTING COMMITMENT. I WISH TO SUBMIT HIS FULL TESTIMONY FOR THE RECORD AND WOULD LIKE TO SUMMARIZE SOME KEY POINTS WHICH WE BELIEVE ARE RELEVANT TO A VIABLE NUCLEAR OPTION FOR LONG TERM U.S. ENERGY SECURITY.

IN OUR VIEW, NUCLEAR POWER CONTINUES TO BE THE ONLY ECONOMIC ALTERNATIVE TO AN EXCESSIVE RELIANCE ON FOSSIL FUELS. NONE OF THE POWER SOURCES AVAILABLE TO THE U.S. ARE WITHOUT THEIR PROBLEMS, BUT ON BALANCE, IN OUR VIEW, NUCLEAR POWER CAN BE THE MOST ECONOMIC, SAFEST, MOST ENVIRONMENTALLY BENIGN SOURCE FOR THE FUTURE. IT WOULD BE A TRAGEDY FOR THE U.S., WHICH LED THE WORLD'S PEACEFUL NUCLEAR PROGRAM IN THE DEVELOPMENT OF ECONOMIC NUCLEAR ENERGY, TO BE DENIED ITS FUTURE USE BECAUSE OF ARTIFICIAL BARRIERS. IT WOULD BE A FAILURE OF OUR GOVERNMENT AND INDUSTRIAL SYSTEMS IF WE WERE NOT ABLE TO DEVELOP NEAR OPTIMUM TECHNICAL AND SOCIAL ARRANGEMENTS FOR EACH OF OUR POWER SOURCES SO THAT WHEN THE NEED AROSE OUR NATION COULD CHOOSE THE MOST SUITABLE SOURCE FOR THE TIME. WE ARE NOT SUGGESTING THAT WE EMBARK ON A NEAR-TERM PROGRAM TO BUILD MORE NUCLEAR PLANTS BUT RATHER THAT WE DO THE NECESSARY WORK NOW TO MAINTAIN NUCLEAR POWER AS A MEANINGFUL OPTION FOR THE FUTURE.

WE BELIEVE THERE ARE TWO PRINCIPAL GOALS TO BE ADDRESSED IN THE DOE CIVILIAN REACTOR PROGRAM.

1. A FOCUSED PROGRAM THAT ASSURES U.S. ENERGY SECURITY FOR THE LONG TERM, AND TO THIS END
2. REVIVAL OF THE U.S. NUCLEAR OPTION.

FAVORABLE SOLUTION TO THE SHORT TERM GOAL IMPLIES THE USE OF THE LIGHT WATER EACTOR (LWR).

HE LONG TERM GOAL CAN BE SATISFIED WITH THE LIQUID METAL REACTOR (LMR) TECHNOLGY WHICH INCLUDES THE BREEDER. THE LWR AND LMR GOALS ARE COMPLIMENTARY AND OTH SHOULD BE PURSUED.

HILE THERE ARE MANY SPECIFIC CONSTRAINTS TO A VIABLE U.S. NUCLEAR OPTION, THE OST SIGNIFICANT ARE INSTITUTIONAL FACTORS BEYOND THE CONTROL OF THE PRIVATE ECTOR. TO BE MORE SPECIFIC, THE EXISTING U.S. REGULATORY PRACTICES AND

PROCEDURES CONTROLLING THE ENVIRONMENT FOR CONSTRUCTION OF NUCLEAR PLANTS MAKE THEIR SCHEDULES TOO LONG, THEIR COST TOO HIGH, AND THEIR UNPREDICTABILITY TOO GREAT. THE PRODUCT IS NOT THE ISSUE. U.S. LWR DESIGNS ARE STANDARD IN JAPAN (AND FRANCE), ARE ROUTINELY CONSTRUCTED IN 4-5 YEARS BY MULTIPLE UTILITIES AND MULTIPLE SUPPLIERS AND PROVIDE EXCELLENT OPERATING PERFORMANCE AND GOOD ECONOMICS.

GENERAL ELECTRIC SUPPORTS LEGISLATIVE REFORMS IN THE LICENSING OF NUCLEAR PLANTS. WE SUPPORT ONE STEP LICENSING, LIMITS TO BACKFITTING AND PRE-APPROVAL OF SITES. TO BE SUCCESSFUL, THESE REFORMS REQUIRE STANDARDIZED DESIGNS ENTAILING VERY LARGE INVESTMENTS BEFORE IT IS CLEAR THAT THE ENVIRONMENT NECESSARY FOR SUCCESSFUL NUCLEAR POWER DEPLOYMENT HAS RETURNED.

U.S. REACTOR MANUFACTURERS HAVE CONTINUED TO MAKE SIGNIFICANT TECHNOLOGICAL INVESTMENTS BY WORKING WITH OVERSEAS PARTNERS AND CUSTOMERS WHERE THE ENVIRONMENT FOR NUCLEAR POWER IS MORE FAVORABLE. THESE PARTNERS AND THEIR GOVERNMENTS HAVE RECOGNIZED THE VALUE OF THIS U.S. CAPABILITY AND MAINTAINED THEIR LONG STANDING RELATIONSHIPS IN THE DEVELOPMENT OF ADVANCED DESIGNS. WE NOW HAVE ADVANCED LIGHT WATER REACTOR DESIGNS THAT CAN BE ADAPTED TO AND DEPLOYED IN THE UNITED STATES IF WE CAN SOLVE THE INSTITUTIONAL CONSTRAINTS TO THEIR USE.

THE LWR PROGRAM PROPOSED BY DOE AND APPROVED BY CONGRESS IS A MAJOR STEP TO ELIMINATING THESE CONSTRAINTS. PRIVATE INDUSTRY ALONE CANNOT BE EXPECTED TO MAKE SUCH INVESTMENTS FAR IN ADVANCE OF POTENTIAL USE WHEN FACED WITH THE HIGH DEGREE OF UNCERTAINTY IN THE U.S. ENVIRONMENT. THE DEPARTMENT OF ENERGY'S ALWR CERTIFICATION PROGRAM PROVIDES THE U.S. GOVERNMENT'S DEMONSTRATION OF ITS RESOLVE TO REESTABLISH THE NUCLEAR OPTION IN THE U.S. THIS IS A GOVERNMENT ROLE NOT AN INDUSTRY ROLE. THIS GOVERNMENT PROGRAM, IN CONJUNCTION WITH THE ELECTRIC POWER RESEARCH INSTITUTE (EPRI) PROGRAM AND THE ADVANCED DESIGNS DEVELOPED BY INDUSTRY CAN PROVIDE THE LEADERSHIP AND TECHNICAL BASIS NECESSARY TO ACHIEVE REGULATORY CERTIFICATION OF MODERN STANDARD DESIGNS; CERTIFIED DESIGNS THAT WILL HELP TO EFFECTIVELY CONTROL THE EXCESSIVE COSTS AND SCHEDULES NOW ASSOCIATED WITH U.S. NUCLEAR PLANTS. IN THE CASE OF GE'S ADVANCED BOILING WATER REACTOR (ABWR), WE ARE ENCOURAGED BY THE RESPONSE OF THE NRC AT BOTH STAFF AND COMMISSIONER LEVELS.

WE BELIEVE IT WILL ALSO BE ADVANTAGEOUS TO INCREASE THE FLEXIBILITY OF THE U.S. NUCLEAR OPTION TO BE ABLE TO ECONOMICALLY DEPLOY NUCLEAR PLANTS IN INCREMENTS OF 500-600 MWe. SUCH DESIGNS, HOWEVER, MUST BENEFIT FROM ENHANCED FEATURES SUCH AS SPECIAL SAFETY CHARACTERISTICS TO OFFSET THE DISECONOMY OF SCALE AFFECTING MIDSIZED SYSTEMS. TO THIS END, DOE'S DEVELOPMENT PROGRAM, INITIATED LAST YEAR WITH CONGRESSIONAL SUPPORT, WILL PROVIDE THE TYPE OF DATA NECESSARY TO ASSESS HOW SUCH IMPROVED DESIGNS MIGHT PROCEED THROUGH AN NRC CERTIFICATION PROCESS. AGAIN, WE ARE ENCOURAGED BY THE PROGRESS TO DATE AND BY THE NRC'S NEW POLICY WHICH IS INTENDED TO IMPROVE THE LICENSING ENVIRONMENT AND MINIMIZE COMPLEXITY AND UNCERTAINTY IN THE REGULATORY PROCESS FOR ADVANCED NUCLEAR POWER REACTORS. EPRI HAS INCORPORATED THIS PROGRAM THRUST INTO ITS ADVANCED LWR PLANS AND IS SUPPORTING ITS DEVELOPMENT BASED ON THE DESIGNS FROM THE REACTOR MANUFACTURERS SUCH AS GE. ADDITIONALLY, INTERNATIONAL INTEREST IS GROWING RAPIDLY AND WE BELIEVE A REAL OPPORTUNITY FOR WORLDWIDE COLLABORATION EXISTS.

WE COMMEND THE DEPARTMENT OF ENERGY AND CONGRESS FOR THEIR INSIGHT IN ESTABLISHING THESE IMPORTANT LWR PROGRAMS AND FULLY SUPPORT THEIR CONTINUATION TO A CONCLUSION. WHEN SUCCESSFULLY COMPLETED, THESE MODEST EFFORTS WILL GO A LONG WAY TOWARD RE-ESTABLISHING THE U.S. NUCLEAR OPTION AND COULD RESTORE INDUSTRY'S CONFIDENCE IN THE NUCLEAR MARKET. I URGE YOU TO CONTINUE YOUR SUPPORT IN THE FY1989 BUDGET.

THE REAL PROMISE OF NUCLEAR POWER IS AN UNLIMITED ENERGY SUPPLY THROUGH THE LIQUID METAL BREEDER REACTOR. EVEN WITH A LOW BREEDING RATIO, THE LMR ONCE FUELED, CAN CONTINUE TO MAINTAIN ITS CAPABILITY WITH ESSENTIALLY NO NEW URANIUM SUPPLIES. THIS HAS BEEN THE PROMISE OF LMR DEVELOPMENT FROM THE EARLY INTRODUCTION OF NUCLEAR POWER AND CONTINUES TO BE A GOAL FOR LONG TERM ENERGY SECURITY.

THE DEVELOPMENT AND DEMONSTRATION OF AN ECONOMIC LMR DESIGN IS AN ONGOING WORLDWIDE EFFORT. PROGRAMS TO DATE BASED ON A SERIES OF LARGE MONOLITHIC PLANTS, SUCH AS THE EUROPEAN SUPERPHENIX I, HAVE PROVEN TO LEAD TO HIGH COST DEMONSTRATION PLANTS AND UNCERTAIN FUTURE COMPETITIVE ECONOMICS. THE U.S. DOE ADVANCED LMR CONCEPTUAL DESIGN PROGRAM CARRIED OUT OVER THE PAST THREE YEARS, SHOWS PROMISE OF MAJOR REDUCTIONS IN THE COST OF DEVELOPING AND DEMONSTRATING LMRs THAT CAN BE COMPETITIVE WITH FUTURE COAL AND ADVANCED NUCLEAR SYSTEMS. THE MODULAR LMR APPROACH, SUCH AS GE'S PRISM CONCEPT, WHEN EMPLOYED IN THE U.S. LMR PROGRAM, PROMISES TO REDUCE THE COST OF PROTOTYPE DEMONSTRATION TO LESS THAN A

BILLION DOLLARS RATHER THAN THE MULTI-BILLION DOLLARS ASSOCIATED WITH THOSE LARGE MONOLITHIC DESIGNS. ADDITIONALLY, THIS MODULAR APPROACH SHOULD BE PARTICULARLY ATTRACTIVE FOR THE U.S. UTILITY MARKET SINCE IT WILL PERMIT CAPACITY ADDITIONS IN SMALLER, MORE FLEXIBLE INCREMENTS WHICH REDUCE THE INITIAL INVESTMENT COMMITMENT AND RISK AND ENHANCE THE UTILITY'S ABILITY TO MEET THE UNCERTAINTY IN FUTURE DEMAND GROWTH. , A KEY FACTOR IN THE U.S. ADVANCED LMR DESIGNS, SUCH AS PRISM, IS THE PROMISE OF ENHANCED REACTOR PROTECTION THAT COULD INCREASE PUBLIC ACCEPTANCE OF NUCLEAR POWER ONCE DEMONSTRATED IN A COMPREHENSIVE TEST PROGRAM AND LEAD TO THE REGULATORY CERTIFICATION OF A STANDARDIZED LMR PLANT.

THE DOE IS IN THE PROCESS OF FOCUSING ITS ADVANCED LMR DESIGN PROGRAM TO ACHIEVE THIS POTENTIAL. GE VIEWS THIS EFFORT AS A NATIONAL ENDEAVOR AND HAS, THEREFORE, DEVELOPED A BROAD BASED TEAM OF EXPERIENCED AND COMPLEMENTARY SKILLS. THIS TEAM IS CURRENTLY COMPRISED OF WESTINGHOUSE, BABCOCK & WILCOX, BURNS & ROE, BECHTEL, STEARNS-ROGER DIVISION OF UNITED ENGINEERS, FOSTER WHEELER AND BYRON JACKSON AND HAS BEEN DEVELOPING A PLAN FOR AN ADVANCED LMR PROGRAM BASED ON PRISM AND CONSISTENT WITH DOE PROGRAM PLANS. WE BELIEVE THIS DESIGN FOCUS COUPLED WITH CONTINUED SUPPORT TO KEY NATIONAL LABORATORY RESEARCH AND DEVELOPMENT, SUCH AS ETEC'S STEAM GENERATOR AND SEISMIC ISOLATION PROGRAMS AND OAK RIDGE'S ADVANCED CONTROLS AND SHIELDING PROGRAMS WILL GIVE THE U.S. A SUCCESSFUL PROGRAM AT LOWEST COST AND RISK TO THE GOVERNMENT.

A KEY DEVELOPMENT REQUIREMENT IN A SUCCESSFUL U.S. LMR PROGRAM WILL BE INTEGRATION OF THE REACTOR DEVELOPMENT AND DEMONSTRATION WITH THE METAL FUEL AND FUEL CYCLE DEVELOPMENT AND DEMONSTRATION PROGRAM UNDER WAY AT ARGONNE NATIONAL LABORATORY, KNOWN AS IFR. METAL FUEL IS CURRENTLY THE REFERENCE FUEL FOR THE PRISM CONCEPT. WHILE PRISM CAN UTILIZE EITHER OXIDE OR METAL FUEL WITHOUT A CHANGE IN REACTOR DESIGN, PRISM'S USE OF METAL FUEL OFFERS A BREAKTHROUGH POTENTIAL FOR LMR ECONOMICS. ADDITIONAL ANL DEVELOPMENT TASKS AIMED AT DEMONSTRATING THE RELIABILITY OF PRODUCTION FUEL AND COMPLETING THE DEVELOPMENT OF THE INTEGRAL FUEL CYCLE SHOULD BE ORIENTED TOWARD AND COMBINED WITH THE REACTOR TEST PROGRAM. IT'S LOGICAL THAT THESE TWO PROGRAMS BE INTEGRATED INTO A COMPREHENSIVE EFFORT AS WE BELIEVE THIS WILL CONVINCINGLY DEMONSTRATE THE SELF-PROTECTING NATURE OF THE ADVANCED LMR AND THE ACCEPTABILITY OF FUEL RECYCLE.

WHILE THE ABOVE PROGRAM FEATURES ARE PRIMARILY DIRECTED TOWARD U.S. CONSTRAINTS AND NEEDS, THEIR SIGNIFICANCE AND INNOVATION HAVE BEEN RECOGNIZED BY OTHER NATIONS AND WE BELIEVE IT IS POSSIBLE TO GAIN OVERSEAS PARTICIPATION IN THE U.S. ADVANCED LMR PROGRAM. THE OVERSEAS DEVELOPMENT APPROACH OF LARGE MONOLITHIC SYSTEMS HAS PROVEN TO BE EXTREMELY EXPENSIVE AND NONE HAS PROVEN TO BE ECONOMICALLY COMPETITIVE. THEREFORE, WE HAVE FOUND A GROWING INTERNATIONAL INTEREST IN OUR PRISM CONCEPT. A FOCUSED U.S. PROGRAM AIMED AT AN INTEGRATED REACTOR AND FUEL TEST COULD BRING ABOUT MAJOR INTERNATIONAL PARTICIPATION.

IN CONCLUSION, NONE OF US CAN BE SURE OF HOW LONG WE CAN RELY ON FOSSIL FUELS AS THE PREDOMINANT SOURCE OF OUR ENERGY SUPPLY. NUCLEAR POWER COULD BE A VITAL FACTOR IN ASSURING FUTURE ENERGY SECURITY BUT THIS ASSURANCE IS FAR FROM CERTAIN TODAY.

WE BELIEVE THERE ARE THREE BASIC ELEMENTS FOR A SUCCESSFUL FUTURE NATIONAL NUCLEAR POWER PROGRAM. FIRST, IN THE NEAR TERM, THE NUCLEAR OPTION SHOULD BE PURSUED THROUGH EFFORTS LEADING TO THE REGULATORY CERTIFICATION OF THE ADVANCED LWR DESIGNS. THIS IS A MODEST EFFORT THAT CAN BE COMPLETED IN EXISTING PROGRAMS WITHIN THREE OR FOUR YEARS. SECOND, AND THE SUBJECT OF OTHER HEARINGS, WE MUST PROVIDE A BASIS FOR LONG TERM, INTERNATIONAL COOPERATION BY PUTTING IN PLACE POSITIVE AGREEMENTS WITH OUR NUCLEAR DEVELOPMENT ALLIES SUCH AS JAPAN, AND FINALLY, WE MUST, FOR THE LONGER TERM, PROCEED WITH FOCUSING THE DEMONSTRATION OF OUR ADVANCED LMR CONCEPT AND THE IFR FUEL CYCLE TO ASSURE THESE PLANTS CAN BE CONSTRUCTED AND OPERATED WITH USER CONFIDENCE AND PUBLIC ACCEPTANCE.

WE URGE THE COMMITTEE TO SUPPORT THESE PROGRAMS IN THE FY 1989 BUDGET.

THANK YOU.

STATEMENT OF

DR. BERTRAM WOLFE
VICE PRESIDENT AND GENERAL MANAGER
GE NUCLEAR ENERGY

ON

CIVILIAN REACTOR PROGRAMS

BEFORE THE

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
HOUSE SCIENCE, SPACE AND TECHNOLOGY COMMITTEE

MARCH 17, 1988

My name is Bertram Wolfe. I am Vice President and General Manager for GE Nuclear Energy. I want to thank the subcommittee for your invitation to participate in these important hearings and will direct my statement to developments and actions that could aid the future nuclear power role for improved, long term U.S. energy security.

In my view, nuclear power continues to be the only economic alternative to an excessive reliance on fossil fuels. Yes, there have been growth pains, but our industry is less than 35 years old and, during this period, we have built and are now operating over 300 nuclear plants worldwide. Last year in the United States, nuclear power produced 384 billion KWh of electricity which is equal to our total electric power generation only 35 years ago. Last year the world's nuclear generation of electricity displaced the consumption of one and a half billion barrels of oil. This production has been acknowledged as being a significant factor in the drop in oil prices. Last year worldwide nuclear power generation reduced the discharge of CO_2 into the atmosphere by over a billion tons, or about half the CO_2 discharged by all U.S. fossil fired plants. If the greenhouse effect proves to be a real environmental problem, certainly nuclear is one of our prime candidates for major ameliorating action.

Under such circumstances, it clearly makes sense to provide for the future use of non-fossil energy sources. None of the power sources available to the U.S. are without their problems, but on balance, in my view, nuclear power can be our most economic, safest, most environmentally benign source for the future. It would be a tragedy for the U.S., which led the world's peaceful nuclear program in the development of economic nuclear energy, to be denied its future use because of artificial barriers. It would be a failure of our government and industrial systems if we were not able to develop near optimum technical and social arrangements for each of our power sources so that when the need arose our nation could choose the most suitable source for the time. I am not suggesting that we embark on a near-term program to build more nuclear plants but rather that we do the necessary work now to maintain nuclear power as a meaningful option for the future.

We believe there are two principal goals to be addressed in the DOE Civilian Reactor Program:

1. A focused program that assures U.S. energy security for the long term, and to this end

2. Revival of the U.S. nuclear option.

A favorable solution to the short term goal implies the use of the light water reactor (LWR).

The long term goal can be satisfied with Liquid Metal Reactor (LMR) technology including the breeder. The LWR and LMR goals are complimentary. A resumption of U.S. LWR orders will act as a constraint on fossil fuel prices and increase the commitment of uranium resources. Development of a U.S. LMR option will, in the long run, limit potential uranium price increases resulting from the expanded use of LWRs while providing a means for regaining U.S. nuclear leadership and influence in international nuclear policy. Both goals can and should be pursued.

While there are many specific constraints to a viable U.S. nuclear option the most significant are institutional factors beyond the control of the private sector. To be more specific, the existing U.S. regulatory practices and procedures controlling the environment for construction of nuclear plants make their schedules too long, their cost too high, and their unpredictability too great.

General Electric supports legislative reforms in the licensing of nuclear plants. We support one step licensing, limits to backfitting and pre-approval of sites. To be successful, these reforms require a standardized design entailing very large investments before it is clear that an environment necessary for successful nuclear power deployment has returned.

U.S. reactor manufacturers have continued to make significant technological improvements by working with overseas partners and customers where the environment for nuclear power is more favorable. These partners and their governments have recognized the value of this U.S. capability and maintained their long standing relationships in the development of advanced designs. We now have advanced light water reactor designs that can be adapted to and deployed in the United States if we can solve the institutional constraints to their use.

The LWR program proposed by DOE and approved by Congress is a major step to eliminating these constraints. Private industry alone cannot be expected to make such investments far in advance of potential use when faced with the high degree of uncertainty in the U.S. environment. This government program, in conjunction with the Electric Power Research Institute (EPRI) program and the advanced designs alluded to above can provide the leadership and technical basis necessary to achieve regulatory certification of modern standard designs; certified designs that will help to effectively control the excessive costs and schedules now associated with U.S. nuclear plants.

Under the DOE-EPRI program mentioned, we expect to adopt the overseas designs to U.S. utility requirements and to carry out analyses and tests that will provide the technical verification for a firm and rational certification of the designs. We are confident, from a technical standpoint, that this can be done and progress to date has been encouraging. The regulatory certification that includes both final design approval and the public hearing process will provide the proof that we have the institutional means to enjoy the benefits nuclear power can provide. In the case of GE's advanced boiling water reactor (ABWR), we are encouraged by the response of the NRC at both staff and Commissioner levels.

We believe it may also be advantageous to increase flexibility in the U.S. to economically deploy nuclear plants in increments of 500-600 MWe. Such designs must benefit from enhanced features such as special safety characteristics to offset the diseconomy of scale affecting midsized systems. To this end, DOE's development program, initiated last year with Congressional support, will provide the type of data necessary to assess how such improved designs might proceed through an NRC certification process. Again, we are encouraged by the progress to date and by the NRC's new policy which is intended to improve the licensing environment and minimize complexity and uncertainty in the regulatory process for advanced nuclear power reactors. EPRI has incorporated this program thrust into its advanced LWR plans and is supporting its development based on the designs from the reactor manufacturers such as GE. Additionally, international interest, in these designs such as in Japan and Europe, is growing rapidly and we believe a real opportunity for worldwide collaboration exists.

The LWR is clearly the technology of choice for the near term. It has received extensive development and has a well established industrial infrastructure and experience base. We commend the Department of Energy and Congress for their insight in establishing these important programs and fully support their continuation to a conclusion. When successfully completed, these modest efforts will go a long way toward re-establishing the U.S. nuclear option and could restore industry's confidence in the nuclear market. I urge you to continue your support in the FY1989 Budget.

The revival of the LWR and its widespread use raises the issue of the long term future of nuclear power. The LWR systems rely on the economic availability of a finite resource, uranium. Although there appears to be sufficient uranium to supply LWR's for at least several decades, the real promise of nuclear power is an unlimited energy supply through the liquid metal breeder reactor. Even with a low breeding ratio, the LMR, once fueled, can continue to maintain its capability with essentially no new uranium supplies. Therefore, introduction of the LMR can eliminate the uncertainty over uranium supply and assure that nuclear power can maintain essentially any level of economic capacity that may be required. This has been the promise of LMR development from the early introduction of nuclear power and continues to be a goal for long term energy security.

However, the development and demonstration of an economic LMR design is an ongoing worldwide effort. Programs to date based on a series of large monolithic plants, such as the European Phenix and SuperPhenix I, have proven to lead to high cost demonstration plants and little hope of future competitive economics. The U.S. DOE Advanced LMR conceptual design program carried out over the past three years, shows promise of major reductions in the cost of developing and demonstrating LMRs that can be competitive with future coal and advanced LWR systems. The modular LMR approach, such as GE's PRISM concept when employed in the U.S. LMR program, promises to reduce the cost of prototype demonstration to less than a billion dollars rather than the multi-billion dollars associated those large monolithic designs. Additionally, should there be need for design modifications as a result of the tests, a retest can be accommodated more readily under the modular reactor approach. This approach should also be particularly attractive for the U.S. utility market since it will permit capacity additions in smaller, more flexible increments which reduce the initial investment commitment and risk and enhance the utility's ability to meet the uncertainty in future demand growth.

A key factor in the U.S. advanced LMR designs, such as PRISM, is the promise of enhanced reactor protection that could increase public acceptance of nuclear power once demonstrated in a comprehensive test program. This program can lead to the regulatory certification of a standardized LMR plant that allows nuclear plant construction with more predictable costs and schedules, a necessary ingredient for utility confidence.

The DOE is in the process of focusing its advanced LMR design program to achieve the potential just described. GE views this effort as a national endeavor and has, therefore, developed a broad based team of experienced and complementary skills. This team is currently comprised of Westinghouse, Babcock & Wilcox, Burns & Roe, Bechtel National Inc., Stearns-Roger Division of United Engineers and Constructors, Foster Wheeler and Byron Jackson and has been jointly developing a plan to carry forth an advanced LMR program based on PRISM and further development of U.S. LMR design technology consistent with DOE program plans. We believe this design focus coupled with key National Laboratory research and development programs, such as ETEC's steam generator and seismic isolation programs, will give the U.S. a successful program at least cost and risk to the government.

A key R&D requirement in a successful U.S. LMR program will be integration of the reactor development and demonstration with the metal fuel and fuel cycle development and demonstration under way at Argonne National Laboratory, known as IFR.

Progress in this program has demonstrated the feasibility of the metal alloy fuels in LMRs to achieve a reasonable burnup. This fuel also promises enhanced reactor protection and is currently the reference for the PRISM concept. While PRISM can utilize either oxide or metal fuel without a change in reactor design, PRISM's use of metal fuel offers a breakthrough potential for LMR economics. Additional development tasks aimed at demonstrating the reliability of production fuel and completing the development of the integral pyrometallurgical reprocessing, currently under way by ANL, should be oriented toward reactor use and should be combined with the reactor test program. Fuel development alone cannot overcome the constraints to the LMR without a viable and competitive reactor system. Therefore, it is logical that these two programs be integrated into a comprehensive effort and, thus, we strongly support this fuel development. We believe this integrated program will convincingly demonstrate the self-protecting nature of the advanced LMR and the acceptability of fuel recycle and, therefore, help eliminate the institutional constraints that have contributed to the excessive costs projected for the LMR in the past.

While the above program features are primarily directed toward U.S. constraints and needs, their significance and innovation have been recognized by other nations and we believe it is possible to gain overseas participation in the U.S. advanced LMR program. The overseas development approach of large monolithic systems has proven to be extremely expensive and none has proven to be economically competitive. Therefore, we have found a growing international interest in our PRISM concept. A focused U.S. program aimed at an integrated reactor and fuel test could bring about major international participation. GE and its design team have been successful in the past in achieving international participation in our nuclear reactor developments and we would expect similar participation with a commitment to such a promising LMR program.

I believe it is also important to recognize that the success of our nonproliferation policy in the past was largely due to our technical leadership that allowed us to constructively influence nuclear energy development and use in directions acceptable to us. Indeed, it seems to be forgotten that the intent of President Eisenhower's successful Atoms for Peace program was not nuclear power for the U.S., but rather international nuclear technology leadership by the U.S. so that the widespread international movement toward nuclear weapons could be slowed or stopped. If we hope to continue this influence we must continue to have a leadership position in advanced nuclear developments. In the case of the breeder, and the worldwide dream of an unlimited energy supply, the U.S. advanced LMR program mentioned above can once again put us in a technology leadership position.

In conclusion, it is likely that the demand for electricity will continue to grow. The world petroleum problem over the long term is apt to get worse, not better. None of us can be sure of how long we can rely on fossil fuels as the predominant source of our energy supply. Nuclear power could be a vital factor in assuring future energy security but this assurance is far from certain today.

I believe there are three basic elements for a successful future national nuclear power program. First, the near term maintenance of the nuclear option should be pursued through LWR efforts leading to the regulatory certification of our advanced LWR designs. This is a modest effort that can be completed in existing programs within three or four years. Second, and the subject of other hearings, we must provide a basis for long term, international cooperation by putting in place positive agreements with our nuclear development allies such as Japan. This will have the dual effect of aiding in the accomplishment of U.S. nonproliferation goals and demonstrating and exerting U.S. international leadership. And finally, we must, for the longer term, and for international leadership, proceed with focusing the demonstration of our advanced LMR concept and the IFR fuel cycle to assure these plants can be constructed and operated with user confidence and public acceptance.

Industry and government will have failed the American people if we do not place a meaningful nuclear option before them. Recent developments and actions by the Department of Energy and Congress show recognition of this situation and promise a redirection and focus of the civilian reactors program that can indeed result in meaningful choices for the American public. The current LWR program appears well founded and should continue as planned. The LMR can assure our long term energy security and we now have the opportunity to focus the program and demonstrate that an advanced LMR concept of U.S. origin can lead to this promise.

We urge the Committee to support these programs and provide guidance on these priorities for the advanced reactor program.

DR. BERTRAM WOLFE

Vice President and General Manager
GE Nuclear Energy

Dr. Wolfe received his B.A. in Physics from Princeton University in 1950 and his Ph.D. from Cornell University in 1954. He has been in the nuclear energy field since 1955, spending all but two years at General Electric. Dr. Wolfe has worked in almost all phases of nuclear energy form reactor design to fuel supply to waste management to development of new reactor concepts. He is Vice President and General Manager of GE Nuclear Energy, responsible for all GE activities in the nuclear power industry. He is a member of the Board of Directors of the Nuclear Management & Resources Council, U.S. Council for Energy Awareness, Nuclear Power Oversight Committee, and the American Nuclear Energy Council. He is a Fellow of the American Nuclear Society and in 1988, was elected Vice-President, President-Elect. He served as President of the American Nuclear Society from June 1986 to June 1987. Dr. Wolfe is a Professional Engineer in the State of California, and is a member of the National Academy of Engineering. He holds a number of patents in the nuclear field and is the author of several dozen publications concerning nuclear energy technology and energy in general.

Mr. STALLINGS. Mr. Frey.

STATEMENT OF JAMES H. FREY, GENERAL MANAGER—SPACECRAFT OPERATIONS—VALLEY FORCE, ASTROSPACE DIVISION, GE AEROSPACE GROUP, VALLEY FORGE, PA

Mr. FREY. Good morning. I am Jim Frey. I am general manager of the Astrospace Division Plant at Valley Forge, Pennsylvania. We have seen a couple of you people at our plant in the last couple of years. We are pleased to have the opportunity again this year to testify.

I am going to try to emphasize some of the highlights and achievements of the SP-100 Program during the past one and a quarter years of its operation.

As you know, most of you know, the SP-100 Program is developing systems and technologies to meet the electrical power requirements of civil and military space missions planned for the mid-1990's and beyond. The reference design is based on a liquid metal cooled reactor coupled to a thermoelectric conversion system and will provide the technology for power systems from tens to hundreds of kilowatts.

The present Ground Engineering System program will demonstrate a full scale reactor and power conversion assemblies. When the contract was initiated in 1986, we recognized that there were several major programmatic and technical challenges in this program.

Among these were, I guess first and most importantly, the assurance of system safety through all the mission phases, development, launch, on-orbit operation, recovery. The fabrication of the fuel was a major challenge and remains a major challenge. The assurance of capability or compatibility between the nuclear fuel and its cladding, design of thermoelectric cells, technology developments in auxiliary areas such as heat transport, heat rejection, system start-up and demonstrating the long life required of this system in space without maintenance and the development of productive working relationships between the very complex array of organization and skills that are being applied to this program, the industry, the National Laboratories, the Department of Energy, JPL; and then finally and certainly not least the major challenges to complete this program on schedule within cost and demonstrate that it meets the very demanding requirements that have been set for this program.

We are now nearing the first really major milestone on the program, the Reference Flight System Design Review which is scheduled to be held this May and as we approach that significant milestone, I am very proud of the many achievements and accomplishments that have occurred with this very talented team over the last year and a half.

We are indeed well on our way to achieving SP-100 program objectives. Let me briefly run through a few of these accomplishments in the past year.

First of all, we have met, I think, the very challenging task of developing a good team from American industry, American Government and the university. We brought together the participants in the Department of Energy, the National Laboratories and industry. I think we have brought the very best that American industry and government have to offer.

The Jet Propulsion Laboratory is the technical manager of the program for the Department of Energy. It is the prime contractor. It is responsible for the overall design, fabrication, test of the ground engineering system.

The design of the fast-spectrum nuclear reactor and associated nuclear subsystems being conducted by our operation in San Jose, California. This organization was formerly part of GE's commercial nuclear business and has been transferred to my operation, to enhance the management of this program, the SP-100 program. Work on the balance of the system and system architecture and space systems is being performed in my operation at Valley Forge, Pennsylvania.

Under GE's direction, the Westinghouse Corporation is responsible for the radiation shield assembly. ThermoElectron Corporation is responsible for providing the development of advanced thermoelectric materials.

The Oak Ridge National Laboratory is performing important work in the areas of refractory metals and radiation shield materials development. Los Alamos is now producing the fuel which will be used in the Nuclear Assembly Test.

Argonne has conducted critical experiments which have confirmed our safety analysis of the nuclear design and is continuing these critical safety experiments and analysis to further verify our design, and they will continue to do so throughout the life of the program. The Nuclear Assembly Test, a key milestone of the program, will be conducted by the Westinghouse Hanford Company at the DOE Richland, Washington site.

Safety is and will continue to be General Electric's number one priority in this program. During the past year, the project has completed definition of a typical mission profile. This has been used to define safety requirements for the generic flight-system design.

Reactor concepts have been completed which meet all safety requirements defined for this program. Special attention has been given to safety on the launch pad during the boost trajectory and in the operational orbit as well as system disposal after its life. Our analysis show that in all mission phases, the SP-100 design adheres to the highest standards of safety.

There is nothing in this program more important than the assurance of mission safety.

A key element of the SP-100 is the use of reactor fuel derived from the heritage of both commercial nuclear power plants and DOE's advanced liquid metal reactor program. The Los Alamos National Laboratory has converted a portion of its fuel laboratory operation into a fully-qualified uranium nitride pilot fuel plant.

Reactor fuel elements have been fabricated and tested to two-thirds of the SP-100 lifetime requirements. Accelerated life testing will continue years ahead. The challenge of assuring materials' compatibility between the reactor fuel and its cladding has been a critical issue, and has been substantially accomplished through our development of a rhenium/niobium alloy barrier fuel pin.

Innovative manufacturing techniques have been developed to assure a good bond between the liner and the alloy of the cladding, and I think we have had considerable success in that area.

We have made significant progress in refractory metal welding to facilitate the assembly of reactor components. Reactor control drive testing has also been successfully initiated.

Advancements in the thermoelectric cell design, the cells that convert the thermal energy generated by the reactor into electrical energy and the materials that make up these cells, have had considerable progress made in the past year.

Feasibility cells have been built and tested and the flight like cell development program is in progress. Now the Nuclear Assembly Test which is a key milestone as I have said in the program will be conducted at DOE's Hanford, Washington site.

Currently the design of this test reactor is about two-thirds complete, one and a half years into the program and that program is going very well. Complementing the reactor test will be an Integrated Assembly Test of the heat transport, power conversion and waste heat rejection system.

This important test will be conducted at Valley Forge by our operations. Detailed planning for this test is well underway. During the past year, GE has made significant investments in production and laboratory facilities in support of this program.

We have installed a heat pipe development and manufacturing facility, a world-class thermoelectric material development testing laboratory and we have also made significant investments in our facilities in San Jose including high-temperature vacuum chambers, welding facilities and facilities for testing the refractory metal system.

A key factor in the development in the selection of the SP-100 concept was the maturity and scalability of the technology over a wide range of power from tens of hundreds of kilowatts. It is an essentially factor if we are going to be able to apply this technology to multiple missions in the future.

We are pleased that independent review panels from outside the program have confirmed that the maturity and scalability of the SP-100 is suitable to meet a wide range of power requirements for potential missions in the future. These are just a few of the accomplishments to date after the first year and a half or so.

Launch of an operational system will soon become possible. The approach currently is to demonstrate the system with a launch of an SP-100 reactor integrated with an electric-propulsion experiment module.

The SP-100 nuclear technology will be the enabling technology which makes high-power, long-life electric propulsion systems possible. Such systems might be used in interplanetary travel or in transfer of satellites from low to high orbits and vice-versa.

Such a test would demonstrate the SP-100 in orbit. Experience such as this would certainly enhance the user community's confidence in space nuclear power, both its function and its safety.

Now I have to say in the last year the uncertain funding level for the SP-100 program severely taxed our management resources. We have met numerous budgetary constraints and are re-planning our own program and re-scoping the SP–100 program consistent with these physical constraints.

Last year, Charlie Schmidt had an opportunity to testify before this Subcommittee and in that testimony he remarked that it was essential that budgets be maintained at the then planned levels to complete the Ground Engineering phase within five years.

Because of reductions in the budgets since that time necessary to re-plan the program and extend its duration, I would urge this Subcommittee's continued support of the program and at least maintain the currently planned levels so that we can attain the timely availability of the SP–100 program as the prime power source for future space missions.

SP–100 is the key technology, I think, to satisfying the high technology power requirements of NASA interplanetary missions as well as planned missions for SDI and DOD. Missions that require high power in tens to hundreds of kilowatts, particularly those which require a long life and survivability are good candidates for SP–100 applications.

I think it is important to say, however, that enactment of appropriate legislation for nuclear indemnification is essential to the future of the SP–100 program.

Without enactment of an acceptable Price-Anderson Act, the ability of industrial contractors to accept future contracts in this area is in doubt. I think I have heard this morning that favorable action occurred in the Senate yesterday on the Price-Anderson Act.

The completion of the program, I think, will be a significant contribution towards making our nation the leader in space in the next century. I am fully confident in the ability of the SP–100 program team to meet the requirements of the SP–100 program. I think we are going to have a successful program if we can carry it out to completion.

I want to thank you for allowing me to come by and present this brief summary of our accomplishments over the first year and a half of the program. Thank you.

[The prepared statement of Mr. Frey follows:]

STATEMENT OF

JAMES H. FREY
GENERAL MANAGER - SPACECRAFT OPERATIONS - VALLEY FORGE
ASTRO-SPACE DIVISION
GE AEROSPACE GROUP

ON

SP-100 PROGRAM

BEFORE THE

HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY RESEARCH & DEVELOPMENT

MARCH 17, 1988

3/14/88

Good morning Madam Chairman and Members of the Subcommittee. I am Jim Frey, General Manager of the Spacecraft Operations at Valley Forge of the Astro-Space Division. We are pleased to have the opportunity again this year to testify before your subcommittee. In my testimony I will try to touch upon some of the highlights and accomplishments of the SP-100 program which have occurred during the past year.

GE has played a major role in space nuclear power programs for more than twenty years. During this time, GE has been at the forefront of Radioisotope Thermoelectric Generator technology through its work on isotopic heat sources and thermoelectric converters. Space nuclear power has been the enabling technology for nineteen navigational, meteorological, lunar, planetary and communications missions to date. GE participated in over half of these missions. The experience on these missions is coupled with our strong background of over forty years as a leader in the development of commercial nuclear power plants. GE is the only major industrial organization which has both nuclear energy and aerospace expertise under one common management structure. I believe that we are uniquely capable of managing the diverse technical disciplines needed to make SP-100 a success.

The SP-100 program is developing systems and technologies to meet the electrical power requirements of civil and military space missions planned for the mid-1990's and beyond. The reference design is based on a liquid metal cooled reactor coupled to a thermoelectric conversion system and will provide the technology for power systems from tens of kilowatts to a megawatt. Particular emphasis has been placed on system safety and scalability. The present Ground Engineering System program will demonstrate a full scale reactor and power conversion assemblies.

When the SP-100 Contract was initiated in 1986, we recognized several key programmatic and technology development challenges which were essential to program success. Among these were:

- assurance of system safety through all mission phases,
- initial fabrication of SP-100 fuel,
- assurance of compatibility of nuclear fuel and its cladding
- thermoelectric cell design and material developments,
- technology base developments affecting such areas as heat transport, heat rejection, system startup and system lifetime,
- development of efficient, productive working relationships among all the contractors and DOE National Laboratory organizations involved,and
- adherence to budgetary constraints

As we near the Reference Flight System Design Review, to be held in May of this year, we are very proud of the significant progress that has been made in key areas such as safety, system and component design, fuel development and the definition of test facilities and procedures.

We are well on our way to achieving SP-100 program objectives. Let me briefly review some of our accomplishments to date.

We have met the challenge of developing effective working relationships among all program participants including other individual firms and the DOE National Laboratories and have effectively marshalled the national resources needed for the SP-100.

For this program, GE has brought together the strongest technical and management resources in the U.S. in the fields of nuclear reactors, thermoelectric conversion and aerospace technology. In support of DOE, government technical overall project management is being accomplished by the Jet Propulsion Laboratory in Pasadena, California. As the prime contractor, GE is responsible for the overall design, fabrication and test of the SP-100 Ground Engineering System. The design of the fast spectrum nuclear reactor and associated nuclear subsystems is being conducted by our Space Nuclear Engineering and Technologies Operation located in San Jose, California. This operation, formerly part of GE's commercial nuclear business, has been transferred to my operation. Work on the balance of the system and system architecture is performed in my operation at Valley Forge, Pennsylvania.

Under GE's direction, the Westinghouse Corporation is responsible for the design and fabrication of the radiation shield assembly and ThermoElectron Corporation is responsible for providing the development of advanced thermoelectric materials. The Oak Ridge National Laboratory is performing important work in the key areas of refractory metal and radiation shield materials development; Los Alamos National Laboratory has developed the fuel and is now producing the fuel which will be used in the Nuclear Assembly Test; Argonne National Laboratory has conducted critical experiments which have confirmed our safety analysis of the nuclear design and is continuing these critical experiments to further verify our design. The Nuclear Assembly Test will be conducted by the Westinghouse Hanford Company at the DOE Richland, Washington site.

Safety is and will continue to be the program's, and I emphasize to you - General Electric's, number one priority from initial design through development and testing and on to future launches of the SP-100. During the past year, the project has completed definition of the reference mission profile and this has been used to define safety requirements for the reference flight system design.

Reactor concepts have been completed which meet all safety requirements. Special attention has been given to safety on the launch pad, during the boost trajectory and in the operational orbit. Our analysis show that in all mission phases, the SP-100 design adheres to the highest of safety standards.

There is nothing on this program more important than the assurance of system safety.

A key element of the SP-100 is the use of reactor fuel that is based on a long and successful heritage from commercial nuclear power plants and DOE's advanced liquid metal reactor program. The Los Alamos National Laboratory has converted its fuel laboratory operation into a fully qualified uranium nitride fuel pilot plant. We were pleased to support this significant achievement.

Reactor fuel elements have been fabricated by Los Alamos and tested at Hanford which have demonstrated two-thirds of SP-100 lifetime requirements. Accelerated life testing is continuing under a wide range of conditions.

The challenge of assuring materials' compatibility between the reactor fuel and its cladding over the life of the SP-100 has been substantially accomplished through our development of a rhenium/niobium alloy barrier fuel pin. Innovative manufacturing techniques have been developed to assure a good bond between the rhenium liner and the working alloy of the cladding.

We have made significant progress in refractory metal welding to facilitate the assembly of reactor components. Reactor control drive testing has also been successfully initiated.

The thermoelectric cells that convert the reactor's heat to electricity are based on the successful experiences of GE's radioisotope space power systems. Advancements in the thermoelectric cell design construction and material development are being achieved. Feasibility cells have been built and tested and the flight like cell development is in process. Technology development is proceeding in other converter component and assembly areas.

The test of the SP-100 reactor will be conducted in 1991 and 1992 at DOE's Hanford, Washington site in an existing facility. Currently, the test reactor preliminary design is nearly two-thirds complete. Under the direction of the Westinghouse Hanford Company, the test site preliminary design and the restoration of the existing facility have been completed. This facility is now ready for modification for the Nuclear Assembly Test.

Complementing the reactor test will be an Integrated Assembly Test of the heat transport, power conversion, and waste heat rejection systems. This important test will be conducted at an existing facility in Valley Forge, Pennsylvania. This test will use an electrically heated energy source to simulate the reactor, and will demonstrate the thermoelectric power conversion assemblies, the loops that carry heat to the radiators and the heat pipe radiator itself. Detailed planning for this test is underway.

During this past year, GE has made significant investments in new production and laboratory facilities in support of the SP-100. At Valley Forge we have installed a heat pipe development and manufacturing facility and a world-class thermoelectric material development and testing laboratory. Significant investments are also occurring at our San Jose facility including high temperature vacuum chambers and welding facilities for fabrication and testing of the reactor's refractory metal systems.

Supporting the reactor and power conversion tests are a number of technology projects. Among these are development tests of high temperature reactor and radiator materials, heat pipes, thermoelectric electromagnetic pumps, sensors and other critical components of the SP-100 program. All of these developments are well underway.

A key factor in the selection of the SP-100 concept was the maturity and scalability of the technology over a wide power range---from tens of kilowatts to a megawatt. We are pleased that numerous independent blue ribbon panels have confirmed that the maturity and scalability of SP-100 is suitable to meet a wide range of power requirements for potential missions. These are a few of the accomplishments to date.

As the SP-100 program moves through successful tests of the reactor, the power conversion system and heat rejection system, launch of an operational system will become possible. The reference approach currently is to demonstrate the system with the launch of an SP-100 integrated with an electric propulsion experiment module.

Such a test would demonstrate the SP-100 to verify successful in-orbit startup, performance capabilities, reactor control systems and ultimate shutdown. Experience such as this would certainly enhance the user community's confidence in space nuclear power.

The uncertain funding level for SP-100 over the past year has severely taxed our management resources. We're all well aware of the funding limitations being imposed on many programs today. The SP-100 is not exempt from these problems and we have met these budgetary challenges by responding to the Department of Energy's needs by replanning and rescoping the SP-100 program to be consistent with fiscal constraints. I know that this subcommittee, DOE and DOD have been strong supporters of the SP-100 program and we appreciate your support. We are encouraged by the increasing interest being shown in the SP-100 program by NASA and by its decision to become a funding partner along with DOE and DOD.

Last year, in Chalie Schmidt's testimony to this subcommittee, he remarked that it was essential that budgets be maintained at the then planned levels to complete the ground engineering phase within five years. Because of the reductions in budgets, it has been necessary to replan the program and to extend its duration. I would urge your support of the program at the currently planned levels so that we can attain timely availability of the SP-100 as the prime power source for future space missions.

The SP-100 program is developing a space power system which will become the enabling technology for a wide range of future space missions. With this capability, the U.S. will have the ability to meet the needs of missions which can only be accomplished with space nuclear power systems. Such a capability is a key to high power requirements of NASA interplanetary missions, as well as SDI and DOD missions that will necessitate higher power requirements, long life and robust survivability characteristics. GE is pleased to be a part of the nation's space power programs. As we have for over 20 years, we stand ready to serve the Department of Energy, Department of Defense and the NASA in meeting future space power needs; however, enactment of appropriate legislation for nuclear indemnification is essential to the future of the SP-100 Program. Without enactment of an acceptable Price Anderson Act, the ability of industrial contractors to accept future contracts in this area is in doubt.

The completion of the SP-100 will be a significant contribution towards making our nation the leader in space in the next century. I am fully confident in the ability of the SP-100 Program Team to meet the requirements of the SP-100 Ground Engineering System Demonstration Project.

Thank you for allowing me to present this brief overview of the SP-100 program to you. We will be happy to answer any questions which you may have.

Mr. STALLINGS. Thank you, Mr. Frey. Dr. Jones, you may proceed please.

STATEMENT OF DR. JOHN E. JONES, JR., DIRECTOR, REACTOR PROGRAMS, OAK RIDGE NATIONAL LABORATORY, OAK RIDGE, TN

Mr. JONES. Thank you, Mr. Stallings and distinguished Members of the Committee. I am honored to present testimony today on behalf of Oak Ridge National Laboratory. We have three principal areas of activity in the Department of Energy's Advanced Reactor Technology Program. These are modular high temperature gas cooled reactor technology, strategic technologies for advanced concepts, and advanced fuel cycle technology.

I will limit my remarks to the first two areas where drastic budgets in the department's budget request for FY 1989 would preclude the development of technology vital to the success of U.S. advanced civilian reactor concepts.

Let me be candid at the outset of my remarks. We recommend continuation of funding at Oak Ridge National Laboratory in the modular high temperature gas cooled reactor and strategic technology areas. I believe that research and development programs underway at ORNL have been models of effective Federal-private sector cooperation, and have responsively and productively used public funds for important national technology objectives, but for want of comparatively modest funding, we risk throwing away the fruits of many years of research and development which has established ORNL as a world leader in advanced nuclear technologies.

These programs are critical elements in our arsenal for maintaining U.S. technology competitiveness, ensuring that nuclear technology remains a viable future domestic energy option.

Let me turn now to a brief outline of principal activity features of our modular high-temperature gas cooled reactor technology.

MHGTR concept offers both unique safety features and the potential for future high-temperature, high-efficiency gas turbine and process-heat applications.

The safety features of this concept were very well outlined and discussed by the previous panel, and in the interest of time, Mr. Chairman, I will not repeat that part of my testimony.

I would like to cover the fact that the MHTGR concept allows future development of very high temperature reactors to produce electricity and process heat. Thermal efficiencies 50 percent higher than current reactor systems are achievable. The importance of the nuclear process heat option may arise sooner than previously anticipated because of mounting concerns over the greenhouse effect and other side effects of burning fossil fuels.

I have provided separately a discussion of the significant progress which has been achieved in this technology development activity underway at Oak Ridge National Laboratory, and the substantial international cooperation which has been established with the Federal Republic of Germany and Japan.

In summary, we support the $35 million national HTGR program as proposed by Gas-Cooled Reactor Associates as a minimum program. It is time for the U.S. to move forward aggressively with this important technology.

Turning now to the second major topic, strategic technologies for advanced concepts, strategic technologies under development at Oak Ridge National Laboratory directly support the PRISM and SAFR advanced liquid metal reactor concepts that you are hearing about on this same panel. These technologies contribute to the inherent safety and international competitiveness of LMR's, as well as other advanced reactor concepts under consideration by DOE.

ORNL's strategic technologies include advanced controls, advanced instrumentation, advanced shielding technology, high-temperature materials and structural design, and robotics technology. These are enabling technologies, broadly applicable and vital to success of the advanced reactor program. Benefits include enhanced safety and licenseability, increased reliability and availability, and improved economics and increased U.S. competitiveness in the international marketplace.

Mr. Chairman, we are deeply concerned that the Department of Energy's budget request for fiscal year 1989 provides no funds for continuing any of these technology programs. We believe technology is the foundation of the advanced reactor program, without which the U.S. can have no commercially viable advanced concept.

We are at an important juncture where we stand to lose our technology to other nations.

I will briefly provide an indication of the significance of these strategic technologies.

First, with regard to advanced controls. Next-generation plants must adopt modern digital technology featuring intelligent control strategies to enhance the operator's understanding and management of the entire system. This progress in reactor controls was one of the first and primary recommendations of the Kemeny Commission following the Three Mile Island accident.

ORNL's role is to pull all of the many diverse development activities ongoing in the U.S. together into an integrated system by providing validated design methods, tools and codes to advance concept designers.

During this past year we have developed an advanced model of human operator performance, explored improved control strategies for multi-modular plants, and converted existing LMR plant models into a common format.

A comprehensive five-year program plan was completed just in the last few months. As an indication of the potential of this technology, we estimate the direct benefit, enhanced safety and plant investment protection is worth approximately $36 million per plant per year.

Similarly, a $4 million per plant per year savings is expected in operating costs because of the reduced staffing requirements with automation. An automated control system can significantly increase the availability of a nuclear plant. The potential value of increased availability in the existing fleet of U.S. nuclear plants, for example, would be approximately $350 million per year for each percentage point increase in availability.

And I might note that the average availability of U.S. plants lags behind the more automated Canadian CANDU plants.

In advanced instrumentation an improved neutron flux monitoring system under development at ORNL would yield a savings of $12 million per plant.

In shielding technology, a capital cost savings of $20 million per plant is projected for the advanced boron carbide shielding material under development at ORNL in the Japanese-American shielding program designated JASPER, and co-funded by PNC of Japan. This program has been severely impacted during this past year by the shutdown of the Tower Shielding Facility in Oak Ridge. We were very disappointed by the recent directive from the Department of Energy to prepare a permanent shutdown plan for this facility.

In view of the importance of the JASPER program to U.S. advanced concepts and our contractual commitment to Japan, we believe this program must be completed, and it has about a year and a half remaining for completion.

Turning to high-temperature materials and structural design, earlier this year in cooperation with GE, Rockwell, and the Department of Energy, we developed a plan for completing the essential tasks required to bring the material and structural technology development effort for advanced LMR concepts to completion over a four-year period.

A significant part of this overall effort is concerned with finalizing work on modified 9Cr-1Mo steel, which is an advanced alloy developed at ORNL specifically for advanced high temperature reactors.

Rockwell estimates that use of this material would result in $150 million in cost saving per plant. The importance of completing development of this material is also underlined by the fact that this is one of four areas targeted late last month by the Department of Energy and the Japanese for collaboration.

A comment, if I may, relative to these last two items, shielding and high-temperature structural materials, which involve collaboration with Japan. I understand Secretary Herrington has indicated we expect up to 50 percent of costs for Supercollider to be provided by international collaborators, especially Japan. In view of this expectation, and many other major areas of collaboration being promoted by the Department, unilateral termination of these modest joint programs which the Japanese value very highly would seem to me to be penny-wise and pound-foolish. If we do not have the will and common sense to be reliable partners in these small projects, how can we be relied upon to complete a project that takes 10 years and billions of dollars to complete?

Finally, in robotics, ORNL's leading coordinated team effort to pursue the development and deployment of advanced robotic systems capable of performing surveillance, maintenance and repair tasks in nuclear energy facilities. Again, a cooperative five-year plan is being pursued. In addition to the ORNL team—excuse me, in addition to ORNL, the team involves the University of Florida, Odetics, the University of Michigan, University of Tennessee, Combustion Engineering, Remotec, University of Texas, and Martin-Marrietta Aerospace.

This represents an effective teaming arrangement in work of key importance. Not only is the work important, but the project is also a good role model for teaming amongst such institutions in the national interest. We believe the DOE decision to terminate this program is therefore doubly unfortunate. You will be hearing a little more about this from Dr. Gonzales in the next panel.

In conclusion, Mr. Chairman, these strategic technologies are key to the enhanced safety and economic competitiveness of all U.S. advanced reactor concepts. ORNL has played a strong national role in each of these technologies over many years, and has established an international preeminence in these areas. No funding has been provided in the DOE FY 1989 budget for these technologies. We believe that a level of $10 million would be sufficient to continue these strategic technologies for advanced concepts.

We cannot let our final and most precious part of the nuclear business, our technology leadership, be lost to other countries.

Thank you very sincerely for the opportunity to testify.

[The prepared statements of Dr. Jones follow:]

TESTIMONY OF

JOHN E. JONES JR.
DIRECTOR, REACTOR PROGRAMS
OAK RIDGE NATIONAL LABORATORY

ON THE FY-1989 DOE AUTHORIZATION FOR ADVANCED REACTOR PROGRAMS

before the
ENERGY RESEARCH AND DEVELOPMENT SUBCOMMITTEE
OF THE
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

March 17, 1988

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
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TESTIMONY OF

JOHN E. JONES JR.
DIRECTOR, REACTOR PROGRAMS
OAK RIDGE NATIONAL LABORATORY

BEFORE THE
ENERGY RESEARCH AND DEVELOPMENT SUBCOMMITTEE
OF THE
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

March 17, 1988

Madam Chairman and Members of the Committee, I am honored to present testimony today on behalf of Oak Ridge National Laboratory. We have three principal areas of activity in the Department of Energy's Advanced Reactor Technology Program: (1) Modular High-Temperature Gas-Cooled Reactor (MHTGR) Technology, (2) Strategic Technologies for Advanced Concepts, and (3) Advanced Fuel Cycle Technology. I will limit my remarks to the first two areas where drastic budget cuts in the Department's Budget Request for FY 1989 would preclude the development of advanced reactor technology vital to the success of U.S. advanced civilian reactor concepts.

Madam Chairman, let me be candid at the outset of my brief remarks. We recommend continuation of ORNL funding in the MHTGR and Strategic Technologies areas. I believe that the R&D programs underway at ORNL have been models of effective federal/private-sector cooperation, and have responsively and productively used public funds for important national technology objectives. But, for want of comparatively modest funding, we risk throwing away the fruits of many years of R&D which have established ORNL as a world technology leader in advanced nuclear technologies. These programs are critical elements in our arsenal for maintaining U.S. technology competitiveness and insuring that nuclear technology remains a viable future domestic energy option.

Let me turn now to a brief outline of the principal features of MHTGR technology.

Modular High-Temperature Gas-Cooled Reactor (MHTGR)

The MHTGR concept offers (1) unique safety features needed to reduce both public and financial risk in order to revitalize nuclear energy; and (2) the potential for future applications in high-temperature, high-efficiency gas turbine and process heat applications.

The key element of the MHTGR design which makes these safety features possible is the inherent safety of the reactor core. The core consists of multilayered ceramic and carbon-coated fuel particles placed in graphite structural blocks. Considerable experimental evidence both in the U.S. and the Federal Republic of Germany (FRG) shows that the ceramic fuel particles are structurally sound and retain their fission products at any conceivable temperature achievable in a potential accident. The importance of this feature cannot be over-emphasized, for if the radioactive fission products in the core cannot be released in an accident, there is by definition no opportunity for releasing this radioactivity to the environment. The manner in which this is accomplished can be summarized as follows:

- First, the reactor power will decline if temperatures in the core exceed normal operating levels. This action is inherent (based on the negative reactivity coefficient) and does not depend upon action by the plant operators, or automatic insertion of mechanical control rods, or any other plant protection system.

- Second, in addition to the normal systems for cooling the core after shutdown, a passive, natural circulation "chimney" is built into the design to remove heat from the pressure vessel wall. This "chimney" will provide adequate cooling for the core after shutdown, even if the normal cooling systems failed and the helium coolant were lost from the reactor.

- Finally, the design is configured such that conduction of heat to the surrounding earth would provide an ultimate, inherent cooling path sufficient to cool the reactor core after shutdown and protect the public from the release of fission products.

While the present MHTGR is designed for steam-cycle electricity generation, the concept allows future development of very-high-temperature reactors to produce electricity from high-efficiency gas turbines or to utilize high-temperature process heat directly. Thermal efficiencies 50 percent higher than current reactor systems are achievable. Process heat applications may be of greater near-term importance than previously anticipated as concerns continue to mount regarding the greenhouse effect from burning fossil fuels.

I have provided separately a discussion of the significant progress which has been achieved in HTGR technology development activities underway at ORNL and the substantial international cooperation which has been established with FRG and Japan. In summary, we support the $35 million national HTGR program as proposed by Gas-Cooled Reactor Associates (GCRA) as a minimum program. It is time for the U.S. to move forward aggressively with this technology.

Strategic Technologies for Advanced Concepts

Strategic Technologies under development at ORNL directly support two other important advanced reactor concepts — the Power Reactor Inherently Safe Module (PRISM) and Sodium Advanced Fast Reactor (SAFR) advanced LMR concepts. These Strategic Technologies are contributing to the inherent safety and international competitiveness of LMR as well as other advanced reactor concepts under consideration by DOE [i.e., the MHTGR, Advanced Light Water Reactor (ALWR), Advanced Neutron Source (ANS), New Production Reactor (NPR), and SP-100]. Furthermore, the technologies could be used to improve the performance of current reactors.

ORNL Strategic Technologies include:

- Advanced Controls (ACTO) Program incorporating advances in artificial intelligence (AI), man-machine interface, and information management
- Advanced Instrumentation for Reactor Systems
- Advanced Shielding Materials and Methods
- High-Temperature Materials and Structural Design
- Robotics for Reactor Systems

These are enabling technologies vital to the success of the Advanced Reactor Program. Benefits include (1) enhanced safety and licensability, (2) increased reliability and availability, (3) improved economics, and (4) increased U.S. competitiveness in the international marketplace.

Madam Chairman, we are deeply concerned that the DOE budget request for FY 1989 provides no funds to continue any of these technology programs. We believe DOE should reconsider the advisability of abandoning

Strategic Technology development. Technology is the foundation of the Advanced Reactor Program, without which the U.S. can have no commercially viable advanced reactor concept. We are at an important juncture where we stand to lose our technology to other nations. I will briefly provide an indication of the significance of these Strategic Technologies.

Advanced Controls (ACTO) We believe next-generation plants must adopt modern digital technology featuring intelligent control strategies and systems to enhance the operator's understanding and management of the entire system. This progress in reactor controls was one of the first and primary recommendations of the Kemeny Commission following Three Mile Island. Development of artificial intelligence or other automation features is being pursued at virtually every research or test reactor site. ORNL's role is to pull all these diverse development activities together into an integrated system by providing validated design methods, tools, and codes to advanced concept designers.

During this past year, we have developed an advanced model of human operator performance, explored improved control strategies for multimodular plants, and converted existing LMR plant models to a common format. A comprehensive five-year program plan was completed.

The use of fault-tolerant advanced automated control can enhance safety and reduce the probability of a major accident through better operator performance and through its ability to keep complex operating systems within a prescribed operating envelope. Assuming, for example, that the accident probability is reduced by a factor of 10, the direct benefit to plant investment protection alone is approximately $36 million per plant per year.

Similarly, a $4 million per plant per year savings in operating cost for advanced automated plants has been estimated by General Electric.

Historically, at least 15 percent of the forced outages (other than normal refueling outages) result from operator errors. By eliminating operator errors or avoiding situations where such errors might be made, an automated control system could significantly increase the availability of a nuclear plant. The potential value of increasing availability in the existing fleet of U.S. nuclear plants is approximately $350 million per year for each percentage point increase in availability.

While the payoff of these benefits in future plants will depend on the number of new plants coming on line and the net gain in availability attributable to automation, clearly it can be substantial.

Advanced Instrumentation. Advanced instruments under development at ORNL include an improved neutron flux monitoring system featuring high-temperature operation and advanced electronics. A prototype system is now undergoing testing. Rockwell International estimates it will save $12 million per SAFR plant. An automated noise diagnostics system has also been developed and is undergoing prototype testing in the Fast Flux Test Facility (FFTF).

Shielding. The existing Japanese/American Shielding Program of Experimental Research (JASPER) is co-funded by PNC of Japan and has been underway since 1986. The $5 million program is focused on development of design data and methodology for use of advanced shielding material such as boron carbide (B_4C). GE estimates a capital cost savings of $20 million per plant for the PRISM concept by using B_4C shielding material rather than steel.

This program has been severely impacted during this past year by the shutdown of the Tower Shielding Facility (TSF) in Oak Ridge. Extensive organizational and procedural improvements have been completed along with facility upgrades to prepare the unique TSF for restart. We were very disappointed by the recent directive from DOE to prepare a permanent shutdown plan for the Tower Shielding Facility. In view of the importance of the JASPER program and the TSF to all U.S. advanced concepts and our contractual commitment to Japan, we believe this directive should be reconsidered. Our commitment to safe operation of all our research reactors remains firm and foremost.

High-Temperature Materials and Structural Design. ORNL has the lead role to provide the high-temperature materials and structural design technology necessary for the design of safe, reliable, economic, and licensable advanced reactors. Earlier this year ORNL, in cooperation with GE, RI, and DOE, developed a plan for carrying out the essential tasks required to bring the materials and structures technology development effort for the Advanced LMR concepts to completion. This remaining effort required by the designers was jointly estimated to cost about $1.5 million per year over a four-year period.

A significant part of this overall effort is concerned with finalizing work on modified 9Cr-1Mo steel, which is an advanced alloy developed at ORNL over the last 12 years specifically for advanced high-temperature reactors.

According to estimates made by Rockwell International for the SAFR concept, use of this material would result in $150 million in cost savings per plant. The importance of completing data generation and design methods development for this material is underlined by the fact that this is one of four areas targeted late last month by DOE and the Japanese (JAPC/PNC) for collaboration.

This technology has potential for many other applications where materials are used at high temperatures.

Robotics. ORNL is leading and coordinating a team effort to pursue the development and deployment of advanced robotic systems capable of performing surveillance, maintenance, and repair tasks in nuclear energy facilities. A cooperative five-year plan is being pursued. In addition to ORNL, the team involves four major universities and their respective industrial partners:

- University of Florida, Odetics
- University of Michigan
- University of Tennessee, Combustion Engineering, Remotec
- University of Texas, Martin Marietta Aerospace

This represents an effective teaming arrangement among a national laboratory, academia, and industrial partners in work of key importance to the international competitiveness of the U.S. Not only is the work of importance, but the project is also seen as a good role model for teaming among such institutions in the national interest. We believe the DOE decision to terminate the program is therefore doubly unfortunate.

Conclusion. These Strategic Technologies are the key to the enhanced safety and economic competitiveness of all U.S. advanced reactor concepts. ORNL has played a strong national role in each of these technologies over many years, and has established an international preeminence in these areas. No funds have been provided in the DOE FY-1989 budget. We believe that a level of $10 million would be sufficient to continue ORNL Strategic Technologies for Advanced Concepts. We cannot let our final and most precious part in the nuclear business— i.e., our advanced technology — be lost to other countries.

Madam Chairman, thank you for the opportunity to testify. We appreciate your leadership in the Congress, which has allowed the United States to continue a meaningful Advanced Reactor Technology Program.

STATEMENT SUBMITTED FOR THE RECORD
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES

ON THE FY 1989 DOE AUTHORIZATION FOR HIGH-TEMPERATURE GAS-COOLED REACTOR PROGRAM

JOHN E. JONES JR.
DIRECTOR, REACTOR PROGRAMS
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March 17, 1988

INTRODUCTION

The Modular High-Temperature Gas-Cooled Reactor (MHTGR) concept has a high degree of inherent safety, providing assurance that no significant amount of radioactive material will be released to the general public in the event of a major accident. This extremely important feature permits an approach to reactor design which removes human error as a source of major accidents. The MHTGR accomplishes this by incorporating inherent and passive safety features such that fission product retention in the reactor system is assured even when reactor operators take no or incorrect actions; even if the pressure vessel fails, essentially all the radioactivity is contained within the reactor system. The MHTGR has a very high thermal inertia which, when combined with its negative temperature coefficient of reactivity, low unit power level and inherent energy dissipation rate assures reactor shutdown without significant fission product release to the environment. Decay heat from the reactor is transferred by inherent physical laws to passive heat convection systems. Heat transport to the surrounding earth is also a feasible way of removing decay heat and preventing fission product release, even in the event of subversion of all active and passive safety features incorporated in the design.

ORNL strongly supports the MHTGR program and recommends that it be funded adequately to continue design, licensing, and critical technology development for the reference plant. The R&D for base technology development concentrates on validating the practicality of MHTGRs having a high degree of inherent safety and is estimated to cost $63M over four to six years. We further recommend expanding MHTGR international cooperation to enhance the development of technology and safety understanding, including high-temperature materials technology for advanced applications. We support a national MHTGR project initiative with private sector participation.

TECHNOLOGY DEVELOPMENT

With regard to MHTGR technology development, extensive efforts have taken place over the past several years culminating in technology development plans covering fuel, fission products, graphite, and metals behavior. These plans have been established by DOE, ORNL, and industry in direct response to specific MHTGR design and licensing requirements. Careful prioritization of technology development needs has led to rigorous cost control. We are at the stage where the critical experimental technology development program is underway.

Fuel and Fission Products Technology. Fission product retention within the fuel coatings is the key ingredient to achieving passive safety in the MHTGR, and additional studies are needed to demonstrate and validate that expected performance is achieved. Fuel fabrication process development is required to confirm that economic fuel fabrication processes will produce quality coatings which retain their integrity during fabrication and reactor irradiation. Fission product transport studies are needed to conclusively demonstrate adequate retention of fission products within the reactor system during all postulated conditions. The cost of the fuel and fission product technology development program is about $43M.

Graphite Technology. Graphite constitutes a major volume fraction of the MHTGR core region. The graphite technology program effort emphasizes obtaining physical and mechanical property data under all postulated conditions so as to provide for reliable component design. Important determinations for design and licensing support are irradiation creep effects and oxidation characteristics. The cost of the graphite program is estimated to be about $11M.

Metals Technology. The metals technology program for the MHTGR relates primarily to mechanical property data required for reliable component design and to ensure licensability. With regard to the reactor vessel, emphasis is on irradiation effects under normal MHTGR conditions and on material property information pertinent to accident conditions. Long-term testing is needed to complete the materials property data base for the steam generator, hot duct, and core internals; key measurements involve fracture mechanics, mechanical properties, radiation effects, environmental and corrosion effects, and weld properties. The metals technology development program cost is about $9M.

INTERNATIONAL COOPERATION

During recent years, significant progress has been made in international cooperation in MHTGR technology development with the FRG and Japan. The present U.S./FRG Umbrella Agreement covering HTGR technology development has been in place more than 10 years, and much fruitful cooperation has taken place during that period. The U.S./Japan cooperation is more recent, with the DOE/JAERI cooperative arrangement in HTGR research and development being signed in 1985. Both of these cooperative efforts were enhanced by completion of the U.S. base technology development plans which are of considerable interest to our international partners. The DOE international cooperative programs in HTGR R&D result in significant benefits to the U.S. since funding of HTGR development on a world-wide basis is estimated to exceed $150M annually.

U.S./FRG Cooperation. The U.S./FRG cooperation involves (1) a subprogram in metals development which addresses specific areas relative to high temperature mechanical properties and corrosion, (2) a subprogram in fuel, fission products, and graphite which covers sixteen specific investigations including fuels and graphite irradiations, (3) a subprogram related to experiments being conducted in the AVR reactor in the FRG, and (4) a safety subprogram covering analytical model development and licensing and safety analyses. These subprograms have been reoriented and expanded to address MHTGR technology development needs as identified by the U.S. base technology development plans. Specifically, the project work statements in the subprograms are being expanded to provide more cooperation in fuel performance modeling, in experimental measurements of fuel performance under postulated accident conditions, in fission product behavior studies, in reactor physics measurements in the AVR, in graphite irradiation creep behavior, and in experimental measurements of the mechanical and physical properties of metals, including fracture mechanics behavior. In the fuel area, the FRG is irradiating U.S. fuel to examine the hydrolysis behavior of fuel particles, and in return the U.S. will provide the FRG the results of a specific U.S. fuel test. The FRG is presently providing about $75M/year for HTGR activities, with about $35M being expended at the Juelich nuclear research center in fuel, fuel cycle, fission products, graphite, metals, safety and HTR component studies, including about $10M for a major test program at the Arbeitsgemeinschaft Versuchs Reaktor (AVR). The AVR test program addresses important safety and reactor physics features in an operating reactor having characteristics pertinent to MHTGRs. Expanding the U.S./FRG HTGR cooperation increases the amount of technology information available to both parties, while limiting overall technology development costs.

U.S./Japan Cooperation. The U.S./Japan cooperation is being carried out through specific annexes to the cooperative arrangement presently in place. Annexes 1, 2, 3, and 4 are in place. The first covers high-temperature fission chamber testing in the Fort St. Vrain reactor. The second covers a joint fuel test program being performed in the U.S. and jointly funded by the U.S. and Japan, at a cost of about $4.2M over five years. Both U.S. and Japanese fuel are being tested in separate irradiation capsules at ORNL; the irradiation capsule design has been largely completed, and the fuel has been fabricated. Fuel irradiation is scheduled to start the middle of 1988. Annex 3 covers cooperative work on graphite emphasizing irradiation creep studies and fracture mechanics. Annex 4 covers material property information pertinent to the MHTGR and to advanced HTGRs. Another annex has also been drafted, and plans for its implementation are being developed; it addresses issues related to design, safety, and licensing. The present Japanese HTGR program expends about $35M per year, principally in the design of a 30 MW(th) high temperature test reactor, technology development, and component testing. U.S./Japan cooperation also increases the amount of technology information available to both parties, as well as limiting overall technology development costs.

FUTURE BENEFITS

While the present MHTGR is designed for electricity generation (or for cogeneration) using the steam cycle, future Modular Very High-Temperature Reactors (MVHTRs) show promise of supplying energy both for high-efficiency gas turbines and for industrial high-temperature processes. Thermal efficiencies 50% higher than current reactor systems are possible using gas turbine MVHTRs. This leads to very economic units for electricity generation, to reductions in cooling water requirements, and to very efficient cogeneration of thermal energy. MVHTRs also show promise for applications to the steam reforming of methane (for chemicals production), and the gasification of coal and the processing of oil shale (for the production of transportation fuels); all of these applications appear important in the future, when energy independence will be a dominant goal, and also when a hydrogen economy evolves. The use of modular reactor units having a very high degree of inherent and passive safety for gas turbine and for process heat applications appears to be most fortuitous, since it should permit economic siting near industry in appropriate plant sizes. MHTGRs are also well suited for export to other countries needing relatively small power additions, and achieve non-proliferation goals by using low-enriched uranium as the initial fuel and by operating on once-through fuel cycles.

SUMMARY

ORNL strongly recommends support of the MHTGR program at a minimum of $35M in FY 1989 to continue design, licensing, and key technology development for the reference plant. It is time to move forward with this very promising second generation concept. MHTGR development leads to an economically competitive reactor system having a very high degree of passive safety. The modular unit is well suited for both near-term and long-term applications. The concept offers unique features for long-term, high-temperature applications in gas turbine units and process heat systems.

The MHTGR technology development program will provide basic information on material properties and on fission product retention capabilities. This program is focused on the specific needs of the MHTGR concept and is very modest relative to other alternatives, being estimated at $63M over about six years. International cooperation in base technology development contributes to the cost effectiveness of the program by providing an expanded technology base for MHTGR design and licensing.

STATEMENT SUBMITTED FOR THE RECORD
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES

ON THE FY-1989 DOE AUTHORIZATION FOR

STRATEGIC TECHNOLOGIES FOR ADVANCED REACTORS

JOHN E. JONES JR.
Director, Reactor Programs
OAK RIDGE NATIONAL LABORATORY

1. INTRODUCTION

The liquid-metal reactor (LMR) program provides an advanced reactor which is a necessity for the long-term application of fission power. It also focuses on systems having passive safety features to enhance licensability and reduce power costs both now and in the future. At this time, conceptual designs for two modular concepts have been developed and are being improved. The Power Reactor Inherently Safe Module (PRISM) concept design is led by General Electric Company (GE), and the Sodium Advanced Fast Reactor (SAFR) concept design is led by Rockwell International Corporation (RI). Both designs are striving to provide passive shutdown and walkaway safety, and presently incorporate a passive decay heat removal system based on natural circulation air ducts. Each design is capable of utilizing either uranium oxide or uranium metal fuel. These advanced reactor concepts utilize innovative designs involving features such as modern control systems, remote technology, advanced materials technology, and advanced shielding technology to make them economically competitive with foreign and domestic conventional nuclear and fossil-fueled plants.

Strategic technology development at Oak Ridge National Laboratory (ORNL) supports the PRISM and SAFR advanced concept designs in key areas important to the safety and economic performance of these concepts. Most of ORNL's strategic technology development activities support all currently proposed advanced concepts and space nuclear programs, although the principal application is to LMRs.

In addition to the strategic technology development activities highlighted below, ORNL assists the Department of Energy (DOE) in technical and economic evaluation of the advanced LMR concepts. Specifically, ORNL assists in planning, coordination, and documentation of design reviews; development of economic ground rules; and coordination of the economic evaluation of advanced LMR concepts.

2. ADVANCED CONTROL (AUTOMATION)

Modern automated reactor control systems can enhance the economic competitiveness of advanced reactors by increasing their operational reliability, availability, and maintainability; improving their safety and licensability by reducing challenges to the plant protection systems; and significantly reducing the manpower needed to operate the plant.

Automation and passive safety features go hand-in-hand. Through on-line monitoring and surveillance of equipment performance, rapid detection and response to equipment malfunction, and reduction of operator errors, automation can significantly reduce the occurrence of abnormalities in plant operation and prevent abnormalities from becoming incidents. Passive safety assures that incidents will not become accidents. The following examples highlight the potential benefits of such developments:

— The average availability of commercial nuclear power plants in the U.S. was 63% from 1982 to 1986, with many plants shut down for safety modifications. Historically, at least 15% of the forced outages (other than normal refueling outages) result from operator errors. By eliminating operator errors or avoiding situations where such errors might be made, an automated control system could significantly increase the availability of a nuclear plant. The potential value of increasing availability in the existing fleet of U.S. nuclear plants is approximately $350 million per year for each percentage point increase in availability. While the payoff in future plants will depend on the number of new plants coming on line and the net gain in availability attributable to automation, clearly it can be substantial.

— The reliability of nuclear plants is threatened by forced outages, scrams, and trips that challenge the plant protection system. Typically, U.S. commercial nuclear plants are tripped or scrammed 5 to 6 times per year. Operator errors account for half of these events. Each scram or trip represents a stressful transient which is imposed on the plant and equipment, in addition to causing a loss of availability. A modern, automated control system could recognize and respond to situations before they lead to trips, eliminate as many as 90% of the scrams, and minimize the opportunities for human error, thereby substantially improving the plant safety and reliability, particularly in the multimodular designs being proposed as advanced reactor concepts.

— An intelligent, automated control system, capable of evaluating the consequences of a proposed control action, could be designed to select the most benign control maneuver and significantly reduce thermal stresses and thermal cycling which might otherwise be experienced, thus increasing the reliability and extending the useful life of the plant. Our analysis indicates a year's life extension for a 1100 MW(e) plant could be worth $360 million. For 100 plants, the savings would be $36 billion.

— An advanced multimodular plant with a single control room and an automated control system could be operated with a staff of 12 to 16 operators instead of 100 to 120 using conventional control rooms for each module. The reduction in staff could save the ratepayer $10 million per year per plant in labor costs. For 100 plants, the savings would be $1 billion.

Automation is critical to the economic competitiveness of multimodular plants. Next-generation plants must adopt modern digital control technology to make use of these new automated and intelligent control strategies and systems. Today's power plants are based on time-tested analog equipment and controls. Thus the new advanced control systems and strategies must first be demonstrated and tested to provide the necessary confidence to regulators, manufacturers, and power plant operators.

To achieve a practical design for an automated control system for advanced nuclear power plants, ORNL is integrating activities in: (1) control system design, architecture, and components; (2) artificial intelligence for adaptive, predictive, and self-learning control strategies and expert systems for operator support; (3) integrated human-system engineering for allocating responsibilities between humans and computers, and for optimal control complex design; and (4) plant simulation, software development and validation, and system reliability improvement. (Fig. 1)

These integrated activities are being conducted in the Advanced Controls (ACTO) Program. The goal is to provide a national center of excellence in research, development, and testing of nuclear control systems. This program will provide an integrated environment to support the rapid, confident design and testing of advanced control systems that will assure improved operability, reliability, and safety for advanced reactors.

To provide the necessary national leadership in the design of advanced control systems, this program will support four major kinds of activities:

- **Demonstrations of advanced control system design features using current developments in control theory, automation, artificial intelligence, information management, modeling and simulation, and man-machine interaction research.**

  The Advanced Controls Program will provide national leadership in control system design by demonstrating examples of advanced control system designs for nuclear reactors. These demonstrations will be carefully designed to show how state-of-the-art research can be used to help accelerate the transition to fully automated control. For example, the first demonstration occurs in late FY 1988 and will be an advanced, automated control system design for a feedwater system for an advanced LMR. The feedwater train is a complex system that is the origin of incidents causing a significant fraction of lost plant availability in conventional LWRs. A robust non-linear control algorithm will be used in a second demonstration showing a supervisory control system for a multimodule LMR.

These and other demonstrations in following years will help transfer to the reactor industry the benefits of the latest proven advances in control systems strategy, control system and whole-plant simulation, computer-aided software engineering for control systems design, man-machine interaction modeling and analysis, and the other technologies being used within the program.

- **Establishment of a design environment that allows designers to formulate and test various control strategies for the plant of interest quickly and economically.**

The program will provide a centrally located, user-friendly design environment for control system designers within the DOE community. The environment will consist of four parts: (1) networked, intelligent, computer workstations into which have been integrated software tools, graphics capabilities, on-line design guidance, on-line documentation and interfaces to the large plant simulation capability at ORNL; (2) plant/component models and databases useful for control system design and plant simulation; (3) information resources concerning control system strategies for automated control; and (4) man-machine interaction models and guidelines for designing control system interfaces with operators.

- **Testing and validation of advanced control system designs by simulation.**

The ability to simulate an entire plant in real-time is critical to the design of a fully automated plant. The program will provide this simulation capability to the technical community. State-of-the-art advances in computer architectures, software engineering, very high-level languages, area networking, artificial intelligence, and database management will be integrated into a whole-plant, real-time nuclear power plant simulation capability.

- **Guidance in control software and hardware specifications.**

The program will provide standards, guidelines, and specifications for control software and hardware. ORNL will acquire and develop tools and methods for generation of large, standardized software programs needed for automation of nuclear reactors. Methods for locating errors in software programs will be acquired and developed, and software verification and validation procedures will be utilized.

It is essential that the government establish such a central program capability for automation and advanced control research that is fully accessible to all segments of the nuclear industry — large and small industries, utilities, national laboratories, and universities. This is the most cost-effective implementation approach, at least in the near-term. As the markets for nuclear energy expand and the use of automation evolves, similar facilities may be developed by the industry.

In the final analysis, the U.S. stands to reap enormous benefits in power-plant availability and reliability from the incorporation of automated control technology. Furthermore, by eliminating most of the contributing causes to the world's reactor near-accidents and frequent operational upsets, these advanced, automated techniques could also help restore public confidence in the nuclear option. To realize these potential benefits, however, an up-front investment in tools, methods, and supporting staff will be required. This investment will be extremely cost-effective in performance improvement and in the nth unit cost of control systems for future reactors.

3. ADVANCED INSTRUMENTATION FOR REACTOR SYSTEMS

Instrumentation provides an extension of the reactor operator's senses ("eyes, ears, and finger tips") to detect the condition of a reactor and ("hands") to control or alter it (Fig. 2). As many as 20,000 sensors are installed in some plants. Automated control systems require even more sensors to provide information in machine-usable form that a human operator would otherwise obtain by personal inspection. The advanced instrumentation development program will provide the needed signals in such a form, and will replace complicated traditional measurement systems with simplified less-expensive systems. This development is essential for assuring both safety and competitiveness in U.S. reactor designs by providing qualified instrument sensor and system prototypes that can form the basis of future plant designs. Lacking these qualified prototypes, U.S. designers will be forced to follow the "minimum extrapolation" philosophy used for the previous designs and inevitably resort to design compromises for lack of a direct measurement capability.

U.S. instrument experts from the national laboratories and the major reactor vendors have identified specific development requirements for future liquid metal reactor (LMRs) instrumentation. Prominent among them is the need for a high-temperature flux monitoring system, whose detector can be installed within the sodium-filled vessel and operate without the need for costly and complicated cooling systems, and a measuring channel that will reduce the three overlapping measurement modes usually employed to a single-mode wide-range system. Such a system would reduce the system price by about $12 million per plant and reduce the time spent in aligning and calibrating the system. Prototype detectors and a measuring system are being built at ORNL and are being qualified through a joint testing program with Argonne National Laboratory.

The "ears" of an automated control system will be provided by a diagnostic system that acquires and interprets the noise always present on instrument signals and relates changes in noise patterns to changes in the operation or condition of a nuclear reactor. An automated noise diagnostic system was developed by ORNL, demonstrated on the HFIR reactor, used in the startup of TVA's Sequoyah Nuclear Plant, and is now installed in the FFTF reactor. For over three years, this system has monitored the operation of the FFTF and generated a base-line for use in interpreting upset conditions, should they arise. This system is being extended to provide expert advice to an FFTF human operator for upset recovery and maintenance planning, and ultimately to an automated plant controller. Application of this advanced technology has already saved $1 million per day for six months for 10 operating LWRs.

The "eyes" of an automated control system will be provided by fiber-optic devices that can recognize closed valves, open doors, contaminated atmospheres, and leaking pipes (all of which must now be seen by a human operator or analyst), and report those conditions directly to an automated control system, promptly and continuously. The program is now identifying the fiber-optic sensor and communication technology that can be applied to reactor plant monitoring and in-service inspection, and to the transmission of large amounts of data among processors in an automated control system, distributed throughout the nuclear plant. The use of fiber-optics communication technology will eliminate the cost and space needed for many miles of copper signal cables now installed in nuclear plants, saving about half of the approximately $9 million in costs for each new plant.

4. SHIELDING

The present shielding program is a cooperative and co-funded effort with Japan. Use of advanced shielding design techniques and materials can reduce reactor capital costs by $100M for a 1000 MW(e) plant. This savings results from the cost of shielding materials, which can be reduced by as much as a factor of 5 by using boron carbide (B_4C), reducing required design margins due to improved analysis techniques and uncertainty predictions, and optimizing localized shielding for individual components and work areas (Fig. 3). These technology improvements have broad application in all advanced reactor systems as well as space nuclear systems. Particularly for modular designs, feasibility of design options can hinge on the use of advanced shielding techniques and materials. Specific feasibility issues include:

- Interim storage of fuel within the vessel
- Vessel diameter reduction to allow barge/rail shipment
- Dose criteria due to activation of secondary heat-removal system
- Location of in-vessel nuclear instrumentation

Verification of these improved shielding materials and design of methods is underway. A four-year joint Japanese/American Shielding Program (JASPER) to accomplish these objectives is being carried out at ORNL's Tower Shielding Facility. Seven major experiments are planned, with the first having been completed in October 1986 and the second completed in March 1987. The $5 million program is equally funded by Japan (PNC) and the U.S. (DOE).

A recent DOE order to prepare a plan for the permanent closure of the ORNL Tower Shielding Facility will cause an early termination of the JASPER program and will reasonably preclude the needed experimental verification for future advanced shielding technologies and advanced concepts.

5. MATERIALS AND STRUCTURAL DESIGN

ORNL has been and continues to be DOE's leading center of excellence in Materials and Structural Design Technology. Since the safety, reliability, licensability, and economics of advanced reactors depend in large measure on this technology, it is vital to the success of DOE's Advanced Reactor Program and to the competitiveness of the United States in the advanced reactor area. The importance and necessity of the technology was just recently underscored by the preparation of a program plan, jointly with General Electric, Rockwell International, and DOE, for carrying out those minimal remaining technology development tasks required by advanced reactor designers. The jointly estimated cost of this remaining effort is about $1.5 million per year over a four-year period.

A significant part of the overall remaining effort is focused on the addition of a new improved alloy, modified 9Cr-1Mo steel, to the design methodology and database so that it can be utilized in U.S. advanced reactor designs (Fig. 4). Development of this alloy was carried out over a period of ten years, and it has gained broad worldwide acceptance for non-nuclear applications. The present emphasis is on supplying the specific structural design and assessment data and tools required by designers of advanced reactors. Elements of this present effort include the generation of data for design allowable stresses for 60-year designs, the identification of appropriate design analysis methods and failure criteria, and development of the high-temperature fracture assessment procedures needed for safety and reliability assessments.

Completion of these modified 9Cr-1Mo steel tasks will allow the use of the material for advanced reactors, with a large attendant cost savings. For example, Rockwell International has estimated that, for the SAFR concept, use of the material will result in a $92 million cost savings per plant in the steam generators and an additional $57 million per plant cost savings in other primary system components.

Further evidence of the importance of the modified 9Cr-1Mo steel activities at ORNL is the fact that the Japanese (JAPC/PNC) are prepared to contribute $1.2 million to a limited part of the work, provided their share is balanced by DOE. This is one of four areas of potential future collaboration between DOE and JAPC/PNC.

ORNL's role in materials and structural design involves more than just the application of modified 9Cr-1Mo steel. A small number of critical materials and structural design issues remains, involving traditional materials and design methods. For example, structural failures resulting from creep and fatigue damage accumulation have occurred in both fossil and earlier LMR plants. Current LMR design methods and criteria must be improved to preclude such failures in the future. In addition, special new data requirements have arisen that are associated with recent advanced reactor designs. These include data needs associated with a longer 60-year life and with passive safety features.

Nondestructive testing technology is under development at ORNL for remote in-service inspection of components in a sodium environment. Inspection of components such as steam generators and intermediate heat exchangers in situ (that is, in the sodium pool) will save up to $300,000 per day for module downtime and enhance the system reliability and availability.

6. ROBOTICS

A primary motivation for utilizing robotics in nuclear power plants is the reduction of personnel radiation exposure to "as low as reasonable achievable" (ALARA) as recommended by the NRC. The exploitation of advanced robots for hazardous operations will contribute substantially to achieving this goal. Robotic access reducing the number of human entries to sensitive locations has the potential for an increased frequency of monitoring and inspection, resulting in enhanced overall safety and reduced personnel exposure (Fig. 5).

Robotics-related technology is used in nuclear plants today only in limited specialized tasks such as fuel handling and pipe inspection. In a recent survey performed by Battelle, it was found that flange unbolting/rebolting, reactor cavity cleaning, health physics surveys, etc., could not be performed using conventional industrial automation-type robotic systems. It was found that robotics for reactor cavity cleanup and maintenance bolting activities would pay back in less than one year, while health physics survey applications would pay back in about three years. Overall, the study indicated cost savings ranging from $100,000 to $1,000,000 in net present-value/robot, assuming a purchase price for each robot at approximately $200,000 and, most importantly, assuming that they would ultimately be able to reduce reactor outage times.

The development and utilization of robots can potentially improve plant availability by permitting some maintenance tasks within containment to be done remotely during power production. It is believed that the number of tasks which could be accomplished this way is large enough to substantially reduce outage durations. Note that purchased replacement power to substitute for the output of a 1000 MW(e) reactor could cost more than $500,000 per day. According to NRC estimates, every man/rem of personnel exposure has a value to utilities of about $1,000.

The Department of Energy has funded four universities and ORNL to pursue research leading to the development and deployment of advanced robotic systems capable of performing tasks that are hazardous to humans, that generate significant occupational radiation exposure, and/or whose execution times can be reduced if performed by an automated system. The goal is to develop during the next decade a generation of advanced robotic systems capable of performing surveillance, maintenance, and repair tasks in nuclear energy facilities. The four universities and their respective partners include:

- University of Florida, ORNL, Odetics
- University of Michigan, ORNL
- University of Tennessee, Combustion Engineering, ORNL, Remotec
- University of Texas, Martin Marietta Aerospace, ORNL

These organizations are working in a unique teaming arrangement, with ORNL serving as team leader and coordinator.

The team has developed a five-year program plan that defines the R&D during the first phase of this program. The overall strategy of this plan is to achieve the program goals in an efficient and timely manner by utilizing and advancing state-of-the-art robotics technology, a key technology for U.,S. competitiveness in the future. Close interaction between the universities, ORNL, industry, and the manufacturers and operators of nuclear plants is the central theme of this program. Results achieved in the short-term are demonstrated during concerted experiments performed at ORNL on an annual basis, the first demonstration being scheduled for September 1988.

7. RELIABILITY, AVAILABILITY, MAINTAINABILITY (RAM) DATA

This program has also become international with the addition of 50 percent Japanese funding and participation under the Centralized Reliability Data Organization (CREDO). CREDO gathers (1) detailed engineering data on components, (2) failure data, and (3) operating data from U.S. and Japanese facilities.

The purpose is to establish and maintain a well-documented, centralized, comprehensive source of RAM data for use by LMR designers (Fig. 6). The data are required for probabilistic risk assessments and other analyses in support of design and licensing, and in establishing inspection and maintenance practices to achieve high plant reliability and availability. The evolving data base provides information needed to properly design and license LMR systems. Presently the data base includes data on 20,000 components, 1,800 events/incidents, and 1.2 billion component operating hours. Space nuclear power systems will also benefit from the data base.

8. SUMMARY

Following completion of the final concept design reports for PRISM and SAFR, we recommend establishing a reference design incorporating the most attractive features of these concepts for more detailed design and development. **Strategic technology** development efforts at ORNL are directly focused on enhancing the safety and economic competitiveness of such a reference concept. Advanced technology is the key to U.S. participation in the very substantial world market for nuclear power in the future. These efforts have been severely impacted by budget constraints in recent years. ORNL strongly recommends restoring adequate funding for Strategic Technologies for Advanced Reactors.

Fig. 1

THE ORNL ADVANCED CONTROLS PROGRAM SUPPORTS
U. S. DESIGNS OF AUTOMATED CONTROL SYSTEMS

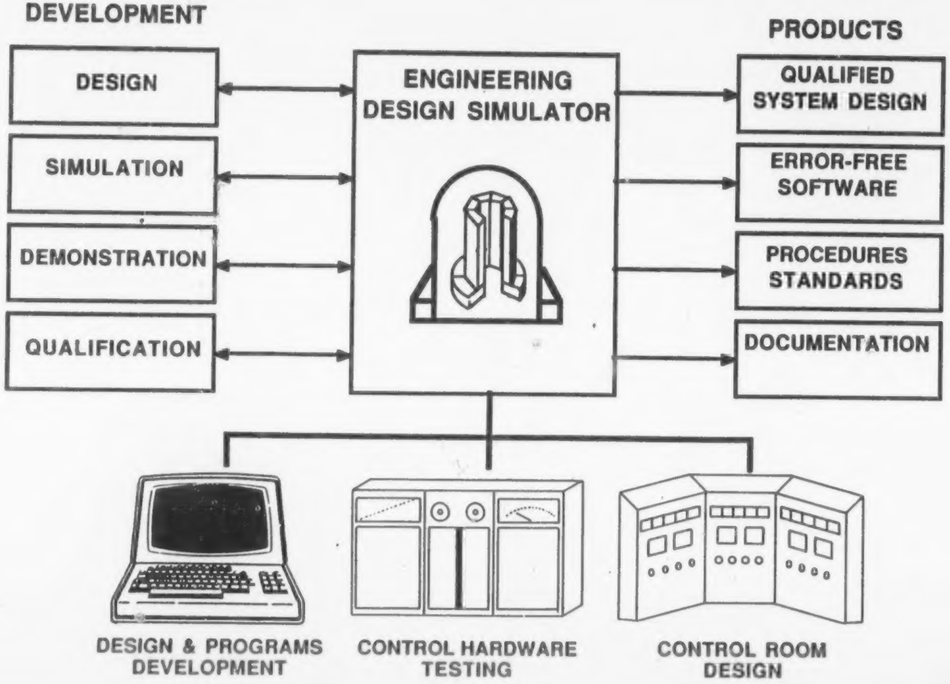
DEVELOPMENT
DESIGN
SIMULATION
DEMONSTRATION
QUALIFICATION
ENGINEERING DESIGN SIMULATOR
PRODUCTS
QUALIFIED SYSTEM DESIGN
ERROR-FREE SOFTWARE
PROCEDURES STANDARDS
DOCUMENTATION
DESIGN & PROGRAMS DEVELOPMENT
CONTROL HARDWARE TESTING
CONTROL ROOM DESIGN

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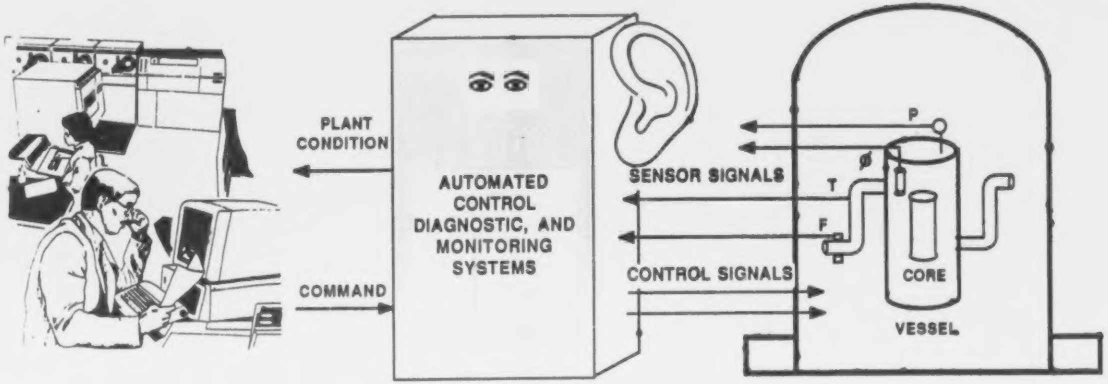
Fig. 2

THE ORNL ADVANCED INSTRUMENTATION PROGRAM WILL PROVIDE THE EYES AND EARS FOR AUTOMATED CONTROL SYSTEMS FOR ADVANCED NUCLEAR REACTOR PLANTS


PLANT CONDITION
COMMAND
AUTOMATED CONTROL DIAGNOSTIC, AND MONITORING SYSTEMS
SENSOR SIGNALS
CONTROL SIGNALS
P
ø
T
F
CORE
VESSEL

ornl

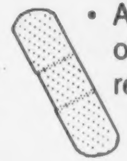
Fig. 3

ORNL-DWG 87M-8680

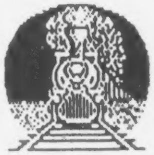
WHY DO WE DO SHIELDING RESEARCH?

***Answer:* Potential Big Cost $aving$**

- Save $ 10–15M in eliminated shield material and reduced system weight



- Avoid multi-M$ cost of post-construction retrofits and delays



- Save $4–8M for 1–2 ft reduction in vessel diameter
- May permit shop fabrication and rail shipment

- Extend lifetime of permanent components
- Reduce replacement frequency for removable components

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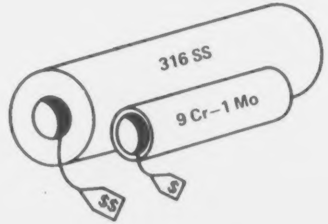
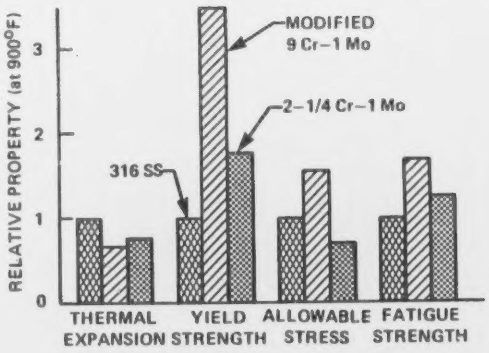
Fig. 4

MODIFIED 9 Cr–1 Mo STEEL HAS SEVERAL ADVANTAGES OVER OTHER CANDIDATE LMR MATERIALS

- LESS COSTLY THAN STAINLESS STEELS
  - LESS MATERIAL REQUIRED
  - SMALLER UNIT COST



- MORE RESISTANT TO THERMAL AND MECHANICAL LOADS



- AS RESISTANT TO STRESS CORROSION CRACKING AS 2–1/4 Cr–1 Mo STEEL (BETTER THAN 316 SS)

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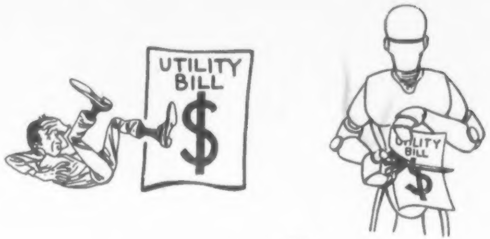
Fig. 5

ORNL-DWG 86-18236R

What Can The Robotics Program Accomplish?

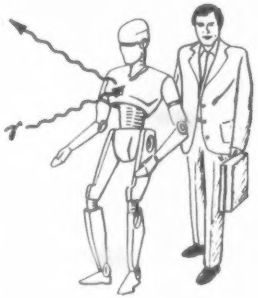
✓ Reduce Operating Costs
Of Nuclear Reactors

Save More Than $500,000/day
By Keeping Plant In Operation



✓ Reduce Personnel
Radiation Exposure

Currently: 400–700 man-rem/plant/year
Robotics: 200–300 man-rem/plant/year



✓ Reduce Nuclear Plant Down-time

By 20 To 50%

ornl
MARTIN MARIETTA ENERGY SYSTEMS, INC.

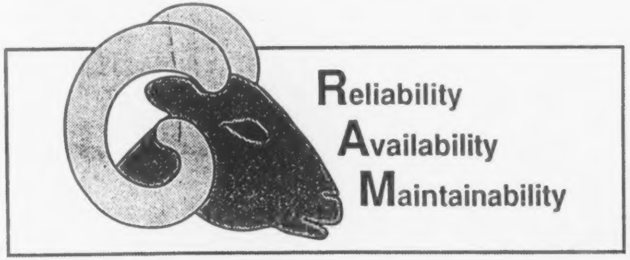
Fig. 6

ORNL-87M-8307

What is CREDO?

(The Centralized Reliability Data Organization)

- The World's Largest Data Base – Covering Liquid Metal Reactor Component Technical Information
- A Data Analysis Center to Support the Data Needs of DOE and Other Users
- An International Cooperative Program Jointly Sponsored by the U.S. DOE and Japan's Power Reactor and Nuclear Fuel Development Corporation (PNC)


Reliability
Availability
Maintainability

Mr. STALLINGS. Thank you, Dr. Jones.

Our final witness, a friend of mine, Mr. Harris, representing Rockwell International.

Mr. Harris.

STATEMENT OF ROBERT E. HARRIS, DIVISION DIRECTOR, WASHINGTON OFFICE, ROCKWELL INTERNATIONAL CORP., ARLINGTON, VA, ON BEHALF OF JOHN McDONALD, DIVISION DIRECTOR, ATOMICS INTERNATIONAL, ROCKET DYNE DIVISION, ROCKWELL INTERNATIONAL CORP., CANOGA PARK, CA

Mr. HARRIS. Thank you very much, Mr. Chairman and Members of the Committee. My name is Robert Harris. I am a Division Director in the Washington office of Rockwell. I am here today on behalf of John McDonald, the Division Director of Atomics International Programs, who has unfortunately taken ill and been hospitalized. I wish to submit his statement for the record, and will briefly highlight selected information.

Mr. STALLINGS. Thank you. It will be included.

Mr. HARRIS. Being the leader in the development of advanced nuclear power systems, Rockwell has had the privilege of addressing this and other Subcommittees many times regarding the U.S. DOE nuclear programs. This is a time when the advancement of the Nation's capability in the areas of both utility electric power and space power are of major importance.

The need to further develop the nuclear power option will not go away. Every year brings the U.S. closer to the time when electric utilities will need to begin adding new generating capacity and a surge in new plant orders is forecast to begin in the late 1990s.

A prudent energy mix is needed for long term national security and, as you well know, there is a close coupling between the gross national product, employment levels, living standards and electrical generating capacity.

Recognizing this, we believe it is imperative that the nuclear option be revitalized, and that improved reactor concepts be developed to better meet utility needs as we move into the next century.

Further, there is a growing recognition of the significant advantages that nuclear power can provide in a variety of military and civilian space missions. We therefore welcome this opportunity to address each of these important areas.

Utilities will need environmentally-clean, naturally-safe and economically-competitive central station power plants. This need, together with the need over the longer term for assurance of national energy security and extension of fuel resources, emphasizes the necessity of a strong DOE advanced reactor program, and in particular a strong liquid-metal reactor development effort.

Today, liquid metal reactor technology stands on a very solid footing, in large part as a result of this Subcommittee's continuing leadership and strong support for the DOE program. Operating results from reactors and major test facilities here and overseas have amply demonstrated fundamental advantages of LMR's such as self-protective safety characteristics, high plant availability, ease of plant operation and low personnel radiation exposures.

The Rockwell Advanced LMR Team, which includes Combustion Engineering and Bechtel, has played an important role in the DOE LMR program. Last December, we completed the conceptual design of a plant which we have named the Sodium Advanced Fast Reactor, commonly referred to as SAFR. Duke Power has recently joined the SAFR team, and is participating in our SAFR Design Improvement Program.

We currently are responding to DOE's Request for Proposal for further development and detailing of an advanced conceptual design of a reference LMR concept. The SAFR team is convinced that our concept best meets utility needs and is the appropriate choice for the DOE reference LMR design. If SAFR is chosen as this concept, the Rockwell team will welcome other qualified organizations to participate in this important design effort.

The innovative 450 MWe SAFR "standard module" design capitalizes on the favorable physical properties of sodium to provide solutions to many of the concerns about nuclear power which have emerged over the last two decades. Attached for the record is a summary description of SAFR and a discussion of the valuable advantages which this concept offers. Also, we have produced a short videotape describing SAFR which we would be happy to show your staff at their convenience.

The SAFR design achieves a higher level of safety than current power plants. It has the inherent capability, based upon the actions of natural forces, to shut down or limit reactor power and assure adequate core and spent fuel cooling under all accident conditions without operator action, external power or support systems. It is not possible for SAFR to have a TMI type accident or Chernobyl type accident. We believe that to earn public acceptance, nuclear plants must offer extremely low risks.

Although SAFR is being developed as a convertor reactor, the design can, with minor modifications, become a breeder when the need arises, thus providing the needed technology bridge to an ensured, long-term fuel supply at stable cost. The SAFR reactor can utilize a modification of the IFR process to use spent LWR fuel elements as a source of fuel and to burn up the long-lived transuranic waste material in these fuel elements. SAFR also has the potential to produce nuclear weapons material having worthwhile advantages over material produced in thermal spectrum reactors.

The current DOE program is paving the way toward capturing the ultimate return on this major national investment in LMR technology development, utilizing strong industrial leadership to provide improved designs with high potential for future commercialization. DOE's plan is to bring private sector participation into the program to support commercialization of the technology.

A key to eventual commercialization is the construction, testing and operation of a first plant connected to a utility grid, thus demonstrating plant economics, construction schedule and performance. Rockwell has suggested an innovative approach for financing this first plant which distributes risks equitably, provides incentives for all participants and limits the need for Government funding.

It should also be noted that utilization of this technology and the new production reactor now being planned can yield a dual national benefit; generation of nuclear weapons material of superior quality and demonstrating important characteristics of the SAFR design.

Turning now to space power, the use of nuclear energy offers the planner of both military and space missions significant advantages in many areas over solar arrays and other power sources. Nuclear power systems are compact, long-lived, orientation-independent, highly survivable and provide high specific power. Attached for the record is a listing of many attributes of nuclear systems that make them advantageous in a variety of space missions.

The U.S. has a long history of using nuclear power in space. Thirty-four safe and successful missions involving isotopic heat sources have been flown, and a Rockwell-supplied nuclear reactor was also launched and operated successfully by the U.S. more than 20 years ago, the only Free World space reactor. And I would just call to your attention that was a SNAP–10A reactor, launched on an ATLAS Agena at Vanderburg in April of 1965. As part of that program we ran an extensive aerospace safety program and also tested extensively five other ground-based space reactor designs.

The DOE has recently contracted with Rockwell for the Dynamic Isotope Power System, commonly referred to as DIPS, a ground demonstration program in which dynamic power conversion is employed to achieve comparatively high power conversion efficiencies while producing power in the 1 to 10 kWe range. The DIPS system builds on existing technology elements and operational experience to provide a power system that is highly reliable, has a safety level much higher than the NRC guidelines for utility nuclear power plants, and is versatile and cost-effective. For systems requiring higher-power levels, DIPS-type power conversion can be coupled to a solar collector or a nuclear reactor. For example, a system comprised of DIPS power conversion units and a SNAP reactor system of the type developed and demonstrated by Rockwell almost two decades ago, could be made available for flight in five years.

A key to the broad exploitation of nuclear power in space is an early flight experiment which would demonstrate the current ability to obtain flight approval. Galileo, DIPS and SP–100 are possible vehicles for this demonstration. With regard to SP–100, it would be prudent, as observed by the DOE-U.S. Air Force Small Reactor Evaluation Panel, to judiciously supplement the current program with selected activities drawing on SNAP technology in order to provide added program, technical and schedular assurance.

I would like now to present a brief profile of the 1988 activities at the Energy Technology Engineering Center. We operate ETEC for the Department of Energy as a GOCO and it supports the Advanced Reactor Program and has for several decades. This multipurpose Government laboratory is located 40 miles northwest of Los Angeles, California and is operated for the U.S. Department of Energy by Rocketdyne Division of Rockwell International.

One of the key lessons from the *Challenger* disaster is that critical components must be tested before their normal operating conditions. At ETEC, tests that evaluate components at extreme conditions, even to the point of failure, are routinely conducted. These tests are improving the safety, cost and reliability of advanced reactor system designs. In one program, ETEC is evaluating reactor piping systems in a unique seismic test facility. Test articles are subjected to tremendous forces and accelerations not achievable anywhere else in the world. Units are tested to failure to eliminate the guesswork for failure prediction.

The development of the shrouded inducer liquid metal pump is proceeding at ETEC under a DOE cooperative agreement with the Japanese reactor manufacturers. Reliable steam generators are critical to the operation of all liquid metal reactor plants and ETEC's steam generator test facility is the world's largest. The addition of a cogeneration plant called Power Pak to the steam generator testing facility is near completion. This plant will generate electricity which will be sold to the local utility, light over 5,000 homes and the revenue will significantly reduce facility operating costs to further test advanced reactor components.

Two steam generator prototypes of different design are now installed and ready for testing in this state-of-the-art facility which simulates the entire heat transfer and power-producing system of an operating reactor.

During 1988, ETEC support of the Advanced Reactor Program has been reduced from prior levels, and the present indicated FY 1989 budget represents a further decline. ETEC's ability to support the Advanced Reactor Program in the important component testing and seismic areas is jeopardized unless Congressional support is forthcoming.

In conclusion, Rockwell continues to believe that liquid-metal-cooled reactors such as SAFR can provide an economic and environmentally clean source of energy which will be acceptable to the utility industry and to the general public when it is needed in the next decade and beyond. Liquid metal reactors, which provide the technology bridge to breeders and energy abundance, have been a clear choice around the world for the next-generation reactor. It would be a serious mistake to deny the advantages of this technology to the country that invented it. Nuclear power is also a key to full achievement of our long-term national objectives in space, and there is belief among potential users that a successful nuclear power flight demonstration would be followed by extensive utilization of this valuable technology asset.

We therefore recommend that an early nuclear power flight demonstration be given high priority in your budgetary provisions. That concludes my remarks, thank you, Mr. Chairman, and Members of the Committee.

[The prepared statement of Mr. McDonald follows:]

TESTIMONY OF
JOHN McDONALD
DIVISION DIRECTOR
ATOMICS INTERNATIONAL
ROCKETDYNE DIVISION
ROCKWELL INTERNATIONAL CORPORATION
ON
NUCLEAR FISSION PROGRAMS
BEFORE THE
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

MARCH 17, 1988

INTRODUCTION

Madam Chairperson, members of the committee, thank you for the opportunity to address you today. I am John McDonald, Division Director of Atomics International at Rockwell International's Rocketdyne Division. Being a leader in the development of advanced nuclear power systems, Rockwell has had the privilege of addressing this and other subcommittees many times regarding the U.S. DOE nuclear programs. This is a time when the advancement of the nation's capability in the areas of both utility electric power and space power are of major importance. Every year brings the U.S. closer to the time when electric utilities will need to begin adding new generating capacity, and a surge in new plant orders is forecast to begin in the 1990s. A prudent energy mix is needed for long-term national security and, as you well know, there is a close coupling between the Gross National Product, employment levels, living standards, and electrical generating capacity. Recognizing this, we believe it is imperative that the nuclear option be revitalized and that improved reactor concepts be developed to better meet utility needs as we move into the next century. Further, there is a growing recognition of the significant advantages that nuclear power can provide in a variety of military and civilian space missions. We therefore welcome this opportunity to address each of these important areas.

I would like to begin by briefly summarizing Rockwell's background on nuclear systems, which we believe qualifies us to discuss these issues. Rockwell International has been a major contributor to the development of nuclear technology since the early 1950s, with particular focus on the design, construction, and operation of liquid metal reactors (LMRs). Rockwell pioneered the development of the LMR and has designed, built, and operated eight LMRs for terrestrial and space applications. For many years, Rockwell has played a major role in the U.S. Liquid Metal Fast Breeder Reactor Program and has been involved in a variety of space nuclear power activities.

Rockwell also designed, constructed, and has operated for 21 years the DOE Energy Technology Engineering Center (ETEC) which is the world's largest facility for testing liquid metal reactor components. ETEC also has a wide range of test capabilities used in testing space power materials, components, and systems.

The need to further develop the nuclear power option will not go away. According to a number of analysts, even with modest growth rates in electrical demand, a critical shortage of generating capacity will develop in the U.S. in the 1990s. Utilities will need environmentally clean, naturally safe, and economically competitive central station power plants. In many areas of the country, the nuclear option will be the economic choice. In some areas, it will become a must due to environmental considerations. This need for pollution-free power, together with the need over the longer term for assurance of national energy security and extension of fuel resources, emphasizes the necessity of a strong DOE Advanced Reactor Program and, in particular, a strong liquid metal reactor development effort.

Today liquid metal reactor technology stands on a very solid footing, in large part as a result of this subcommittee's continuing leadership and strong support for the DOE Liquid Metal Reactor Program. Operating results from reactors and major test facilities here and overseas have amply demonstrated fundamental advantages of LMRs such as self-protective safety characteristics, high plant availability, ease of plant operation, and low personnel radiation exposures.

The Rockwell Advanced LMR team, which includes Combustion Engineering and Bechtel, has played an important role in the DOE LMR Program. Last December we completed a successful 3-year conceptual design effort for an advanced liquid metal reactor which we have named the Sodium Advanced Fast Reactor (SAFR). Duke Power has recently joined the SAFR team and is participating in our current 1-year SAFR design improvement program. We currently are responding to DOE's Request for Proposal for further development and detailing of an advanced conceptual design of a reference liquid metal reactor concept. The SAFR team is convinced that our concept best meets utility needs and is the appropriate choice for the DOE reference LMR design. If SAFR is chosen as this concept, the Rockwell team will welcome other qualified organizations to participate in this important design project.

The innovative 450-MWe SAFR "standard module" design capitalizes on the favorable physical properties of sodium to provide solutions to many of the concerns about nuclear power which have emerged over the past two decades. The factory-fabricated 450-MWe modules would be added at a given site on a schedule to closely match increases in utility load requirements. The SAFR design achieves a higher level of safety than current power plants. SAFR has the inherent capability, based on the actions of natural forces, to shut down or limit reactor power and assure adequate core and spent fuel cooling under all accident conditions without operator action, external power, or support systems. It is not possible for SAFR to have a TMI-type accident or a Chernobyl-type accident. The SAFR Probabilistic Risk Assessment, calculated in accordance with the Nuclear Regulatory Commission (NRC) Procedure NUREG/CR-2300, shows safety risks several orders of magnitude better than NRC safety goals. We believe that to earn public acceptance, nuclear plants must offer extremely low risks such as this.

Attached for the record is a summary description of SAFR and a discussion of the valuable advantages which this concept can offer utilities. Also, we have produced a short videotape describing the SAFR power system, which we would be happy to show the subcommittee and/or staff at their convenience. The SAFR approach incorporates the metal fuel IFR concept and builds on our extensive collaboration with Argonne National Laboratory over the last 4-1/2 years in using a jointly developed pool plant design and, subsequently the SAFR, as a design vehicle to aid in characterizing the IFR concept. In addition, important contributions have been made by other national laboratories (e.g., ETEC, ORNL, and HEDL) to the development and substantiation of SAFR.

The SAFR design is being reviewed in detail through a series of DOE-sponsored meetings with the NRC and with the Advisory Committee on Reactor Safety. We expect that NRC will soon issue a position letter on SAFR licensability based on their detailed review of our Preliminary Safety Information Document. This ongoing interaction will culminate in an NRC Safety Evaluation Report and Licensability letter that will help assure that the evolving SAFR design will ultimately be licensable. Also, we have discussed the SAFR design with a number of utilities and have benefited from their inputs on maintenance, operations, and other areas of user concern. The design has also been reviewed in-depth by special review committees, comprised of experts assembled by the DOE, with very favorable results.

Although SAFR is being developed as a convertor reactor, the design can be converted to a true breeder with minor modifications when the need arises, thus providing the needed technology bridge to breeders and an assured long-term fuel supply at stable costs. The SAFR reactor can also be combined with a modification of the IFR process to use spent LWR fuel elements as a source of fuel and to burn up the long-lived transuranic waste material in these fuel elements. This feature can make SAFR a valuable adjunct to light-water reactor power generation and also reduce the need for long-term radwaste repository storage. In addition, SAFR potentially is capable of producing weapons material which has worthwhile advantages over material produced in thermal spectrum reactors.

The current DOE program is paving the way toward capturing the ultimate return on this major national investment in LMR technology development, utilizing strong industrial leadership to produce improved designs with high potential for future commercialization. DOE's plan is to bring private sector participation into the program to support commercialization of the technology. A key to eventual commercialization is the construction, testing, and operation of a first plant connected to a utility grid, thus demonstrating plant economics, construction schedule, and performance. Rockwell has suggested an innovative approach for financing this first plant, which distributes risks equitably, provides incentives for all participants, and limits the need for government funding. With the lead time required for this project, as well as the anticipated rapid growth in requirements for new electrical generating capacity, it is important that this program move ahead in an orderly fashion. I would like to suggest, in closing this segment of my testimony, that utilization of this technology in the New Production Reactor now being planned can yield a dual national benefit: generation of nuclear weapons material of superior quality and demonstrating important characteristics of the SAFR design.

Turning now to the subject of space power, the use of nuclear energy offers the planner of both military and space missions significant advantages in many areas over solar arrays and other power sources. Nuclear power systems are compact, long-lived, orientation-independent, highly survivable, and provide high specific power. Attached for the record is a listing of many attributes of nuclear systems that make them advantageous in a variety of space missions.

The U.S. has a long history of using nuclear power in space. Thirty-four safe and successful missions involving isotope heat sources have been safely flown, accumulating over 300-million operating hours in space. Nuclear power was an enabling technology for interplanetary probes such as Pioneer and Viking. A Rockwell-supplied nuclear reactor was also launched and operated successfully by the U.S. more than 20 years ago. This represents the only space reactor to have been launched by the free world, whereas USSR has placed a number of nuclear reactor powered spacecraft in orbit. Quoting a recent statement by General Rankine, Vice Commander of USAF Space Division, "It is inevitable that future U.S. military spacecraft will require space reactor power sources."

The U.S. nuclear space power efforts, until recently, have relied on thermoelectric power conversion having performance efficiencies in the range of 3 to 6%. The DOE has recently contracted with Rockwell for the Dynamic Isotope Power Systems (DIPS) Ground Demonstration Program, in which dynamic power conversion is employed to achieve power conversion efficiencies of 20 to 30% while producing power in the 1- to 10-kWe range. The DIPS system builds on existing technology elements and operational experience to provide a power system that is highly reliable, has a safety level much higher than the NRC guidelines for utility nuclear power plants, and is versatile and cost effective. For systems requiring higher power levels, the DIPS-type high-efficiency dynamic power conversion equipment can be coupled to a solar collector or nuclear reactor. For example, a system in which DIPS power conversion units are coupled with a SNAP reactor system (of the type comprehensively developed and demonstrated by Rockwell almost two decades ago) could be made available for flight in 5 years.

A key to the broad exploitation of nuclear power in space is an early flight experiment which would demonstrate the current ability to obtain flight approval. Galileo, DIPS, and SP-100 are possible vehicles for this demonstration. With regard to SP-100, it would be prudent, as observed by the DOE-USAF Small Reactor Evaluation Panel, to judiciously supplement the current program with selected activities drawing on SNAP technology in order to provide added program technical/schedular assurance.

Rockwell is also participating in the SDIO-DOE Multimegawatt Nuclear Space Power Program. In this program the Rockwell concept employs potassium as the working fluid for dynamic power conversion using the Rankine cycle. This closed cycle dynamic system has the highest efficiency of systems operating at equivalent reactor temperature and is a promising candidate to provide power to SDI space-based weapons and other systems.

I would like now to present a brief profile of 1988 activities at the Energy Technology Engineering Center (ETEC). This multipurpose government laboratory, located 40 miles northwest of Los Angles, California, is operated for the U.S. Department of Energy (DOE) by the Rocketdyne Division of Rockwell International Corporation.

One of the key lessons from the Challenger disaster is that critical components must be tested beyond their normal operating conditions. At ETEC, tests that evaluate components at extreme conditions, even to the point of failure, are routinely conducted. These tests are improving the safety, cost, and reliability of advanced reactor systems.

In one program, ETEC is evaluating reactor piping systems in a unique seismic test facility. Test articles are subjected to tremendous forces and accelerations not achievable anywhere else in the world. Units are tested to failure to eliminate the guesswork from failure prediction. This year, testing-to-failure of 6-inch diameter piping systems is being conducted. The results of these tests are already leading to simplified component designs, substantially improved regulations for light water and advanced reactors, and reduction in nuclear plant construction costs.

Another seismic test of worldwide interest is the evaluation of large seismic isolators. These are large, steel-reinforced rubber plugs that can attenuate earthquake effects on large structures, including reactor containment buildings.

ETEC in conjunction with Argonne Laboratory, prominent universities (California Institute of Technology, University of California, and University of Southern California), reactor designers (Rockwell, General Electric, and Bechtel National) have formulated a Seismic Technology Plan that when implemented will provide fundamental advances, cost savings, and reliability gains in the way plants are designed and licensed for seismic events.

Piping systems and valves are also being examined under severe thermal and mechanical loads to assess their reliability during extreme reactor situations. Such tests cannot be performed in operating reactors without endangering the plant. However, ETEC test facilities are designed to duplicate and survive extreme plant operating conditions, and are fully instrumented to record test parameters and component behavior.

Passive air cooling for reactor decay heat removal is being tested in an ETEC facility using a 1/13-scale model of a liquid-metal-cooled, inherently safe reactor system.

In-service inspection systems that move about inside a reactor on monorail tracks are also being evaluated at ETEC. These robotic TV camera devices assure plant operators that reactor air cooling passages are in good condition and free of obstructions.

A major advancement in the efficiency of liquid metal heat transfer systems is the development of the shrouded inducer liquid metal pump. A DOE cooperative agreement with Japanese reactor manufacturers is helping to bring this U.S. design to practical application through development testing at ETEC.

Reliable steam generators are critical to the operation of all liquid metal reactor plants. ETEC's steam generator test facility is the world's largest and is designed to accommodate multiple test articles for steady-state, endurance, and thermal transient testing.

Two steam generator prototypes of different design are now installed in this state-of-the-art facility which simulates the entire heat transfer and power-producing system of an operating reactor. Fossil-fired heaters (70 megawatts total thermal capacity) substitute for reactor core heating. A hockey-stick steam generator design has already undergone preliminary testing, and a helical-coil steam generator prototype will begin endurance testing shortly.

A cogeneration plant, called Power Pak, is being added to the steam generator test facility. Power Pak will convert the steam generated during testing to about 24 megawatts of electricity. This power will be sold to the local utility, light over 5,000 homes, and the revenue will significantly reduce facility operating costs.

The favorable testing economics, made possible by the Power Pak installation, stimulated Japanese participation in the double-wall-tube steam generator program. This third design prototype, a 70-megawatt test unit, is being built in Florida and is scheduled for delivery to ETEC next year.

Testing of several other key reactor subsystems is directly related to ETEC's multiple steam generator test programs. Sodium-water leak detection systems, including chemical and acoustic methods, are being evaluated during steam generator operation.

A parallel program is characterizing the dynamics of sodium-water leaks and control mechanisms for remedial actions.

ETEC is testing instrumentation applications, including high temperature strain gages and the use of fiber optics for reactor control room circuitry.

Two special projects are also designed to take advantage of the versatility of ETEC's facilities. The privately funded Kalina cycle demonstration, a thermal power conversion test, will utilize exhaust gases from one of the steam generator test facility's sodium heaters. A steam injection system, which is a passive safety device for light water reactors, will also use the by-products of steam generator tests.

Space power systems and components require special environmental testing to simulate the rigors of launch effects and the hard vacuum of outer space. ETEC's large and small vacuum facilities are being activated to meet the needs of the SP-100 and DIPS space power programs.

The refractory materials needed for high temperature liquid metal systems to operate reliably in a space vacuum are undergoing special strength and durability testing. Instrumentation and lithium purification systems for the SP-100 are also being developed.

ETEC's off-site activities include the technical management and monitoring of over 700 engineering projects nation-wide in solar heating and cooling, atmospheric fluidized bed combustion, and geothermal power applications.

During 1988, ETEC support of the advanced reactor program has been reduced from prior levels, and the present indicated FY 1989 budget represents a further decline. ETEC's ability to support the advanced reactor program in the important component testing and seismic areas will be severely limited unless Congressional support is forthcoming.

In conclusion, Rockwell continues to believe that liquid-metal-cooled reactors such as SAFR can provide an economic and environmentally clean source of energy which will be acceptable to the utility industry, the financial community, and to the general public when it is needed in the next decade and beyond. Liquid metal reactors, which provide the technology bridge to breeders and energy abundance, have been the clear choice around the world for the next generation reactor. It would be a serious mistake to deny the advantages of this technology to the country that invented it. Nuclear power is also a key to full achievement of our long-term national objectives in space, and there is belief among potential users that a successful nuclear power flight demonstration would be followed by extensive utilization of this valuable technology asset. We therefore recommend that an early nuclear power flight demonstration be given high priority in your budgetary provisions.

1507D/ljm

Attachment 1

THE SAFR CONCEPT FOR THE REFERENCE ADVANCED LIQUID METAL REACTOR PROGRAM

INTRODUCTION

The SAFR modular liquid metal reactor concept, developed during a 3-year Conceptual Design program and being improved during the present 1-year Design Improvement program, offers future users the most attractive features of any type of nuclear power system. The SAFR design capitalizes on the advantageous physical properties of sodium and metal fuel to provide a very high level of safety, low capital and operating costs, and "user friendliness." SAFR can provide solutions to most historical utility nuclear power plant concerns, as summarized in Table 1.

Table 1. SAFR's Solutions to Historical Utility Nuclear Power Plant Concerns

Safety

- Risk of loss of coolant accidents is insignificant
- Possibility of fuel melting essentially zero
- No evacuation requirement expected
- Assured shutdown independent of operator action
- Potential for radioactive spills essentially eliminated

Operations

- Few engineered safety and auxiliary systems—eliminates many potential failure modes
- Very few trip signals to trigger shutdown
- Insensitive to feedwater interruptions
- Very low personnel exposures
- Minimal radwaste generated
- Long life fuel and fast refueling

Economics

- Low generating cost
- Limited cash outlay before power generation
- Minimum safety envelope reduces capital cost
- Shop fabrication and standardized design to simplify licensing and reduce construction uncertainties
- Field construction schedule estimated to be less than 3 years
- Inherent safety protects capital investment

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DESIGN DESCRIPTION

The 450-MWe size of the SAFR power module has been established to be optimum for purposes of (1) being small enough for factory fabrication and barge shipment to sites; (2) incorporating diverse, passive decay heat removal systems; while (3) being large enough to benefit significantly from economies of (e.g., as compared with the PRISM LMR and the modular gas-cooled reactor). The 450-MWe SAFR reactor assembly is shown in Figure 1. SAFR uses a pool-type configuration, in which the reactor core and the primary heat transport system components (pumps and intermediate heat exchangers) are all located within the

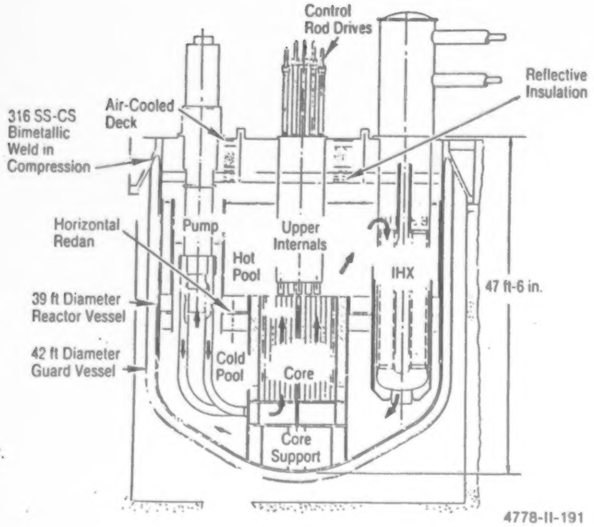

Control Rod Drives
Reflective Insulation
316 SS-CS Bimetallic Weld in Compression
Air-Cooled Deck
Horizontal Redan
Pump
Upper Internals
Hot Pool
IHX
47 ft-6 in.
39 ft Diameter Reactor Vessel
42 ft Diameter Guard Vessel
Cold Pool
Core
Core Support
4778-II-191

Figure 1. SAFR Reactor Assembly

sodium-filled stainless steel reactor vessel. The primary system sodium, which fills the vessel to a depth of about 45 ft, is pumped by two parallel inducer-type mechanical pumps upward through the core, where its temperature increases from 675°F to 950°F. The hot sodium then flows downward through four parallel intermediate heat exchangers, where it gives up heat to the intermediate sodium coolant and then flows to the pump inlets to repeat the cycle.

The core employs a metal alloy fuel, which promises worthwhile cost and safety advantages over oxide fuel. Current design fuel life is 4 years, and the breeding ratio is slightly greater than unity to make up for fuel cycle losses. (The core design has been optimized to enhance inherent safety and minimize busbar costs, not breeding ratio.) Annual refueling of one-fourth of the core is planned, using an offset arm in-vessel fuel transfer machine, mounted in the reactor vessel deck, to transfer assemblies between the core and in-vessel storage. Spent fuel is allowed to decay 1 year in the vessel before being transferred through an A-frame fuel transfer cell to a storage area outside the vessel, where the fuel is cooled by natural convection air.

Figure 2 shows the SAFR flow diagram. (Only one of the two parallel secondary sodium loops and steam generators is shown.) The intermediate sodium heat transfer system uses inducer pumps essentially identical to those of the primary system, and incorporates hockey stick type steam generators with twisted tape "booster tube" inserts. The system employs simple, monoplanar piping, thus greatly reducing capital and maintenance/inspection costs by eliminating the need for spring hangers and snubbers.

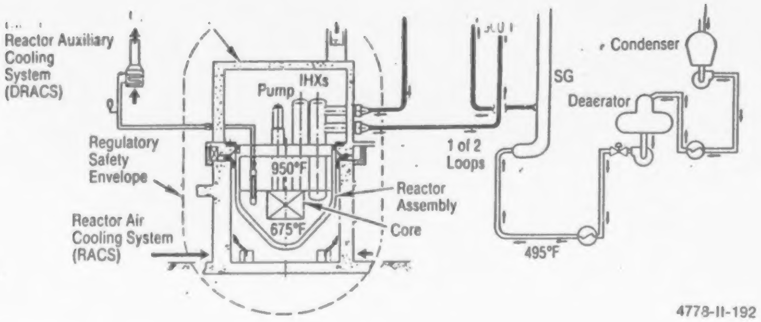

Reactor Auxiliary Cooling System (DRACS)
Regulatory Safety Envelope
Reactor Air Cooling System (RACS)
Pump
IHXs
950°F
675°F
1 of 2 Loops
Reactor Assembly
Core
SG
Condenser
Deaerator
495°F
4778-II-192

Figure 2. SAFR Flow Diagram

Figure 3 highlights important features of the efficiently arranged steam supply system of the SAFR module. Hatches in the reinforced-concrete roof of the reactor containment building permit vertical removal and replacement of equipment for maintenance by the external gantry crane, and minimize the building height. A single gantry crane serves all modules of a multimodule plant plus the maintenance building.

SAFETY AND LICENSABILITY

The SAFR design ensures both public safety and investment protection by means of a variety of passive and redundant features, as illustrated in Figure 4. The design incorporates the inherent capability for reactor shutdown and safe core and spent fuel cooling under all circumstances.

Inherent reactor shutdown is provided by the natural thermal and reactivity response characteristics of the overall core and reactor assembly; these result in safe self-regulation to a low, stable reactor power level even under the extreme circumstances of anticipated accidents without scram, as well as the combined loss of flow/transient overpower/loss of heat sink event without scram. This is the bounding or "worst case" event represented by an earthquake-caused reactivity insertion combined with an off-site power loss causing loss of pump power (elimination of flow) and loss of steam generator (heat sink). The inherent SAFR response, which has already been demonstrated in principal in tests at the EBR-II and in overseas reactors, shuts the reactor down and limits fuel and coolant temperatures to safe levels. With this inherent shutdown capability, a reactor scram no longer has its old meaning and is no longer required for plant safety. However, a reactor shutdown (scram) system is provided protection of the "plant investment," i.e., to avoid the occurrence of abnormal conditions which might require costly repairs.

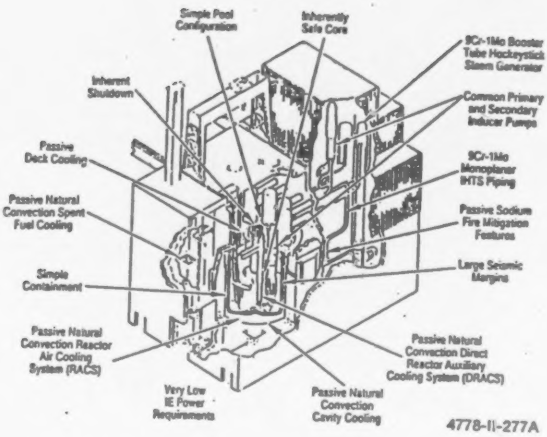

Simple Pool Configuration
Inherently Safe Core
9Cr-1Mo Booster Tube Hockeystick Steam Generator
Inherent Shutdown
Common Primary and Secondary Inducer Pumps
Passive Deck Cooling
9Cr-1Mo Monoplanar IHTS Piping
Passive Natural Convection Spent Fuel Cooling
Passive Sodium Fire Mitigation Features
Large Seismic Margins
Simple Containment
Passive Natural Convection Reactor Air Cooling System (RACS)
Passive Natural Convection Direct Reactor Auxiliary Cooling System (DRACS)
Very Low IE Power Requirements
Passive Natural Convection Cavity Cooling
4778-II-277A

Figure 3. Important NSSS Design Features

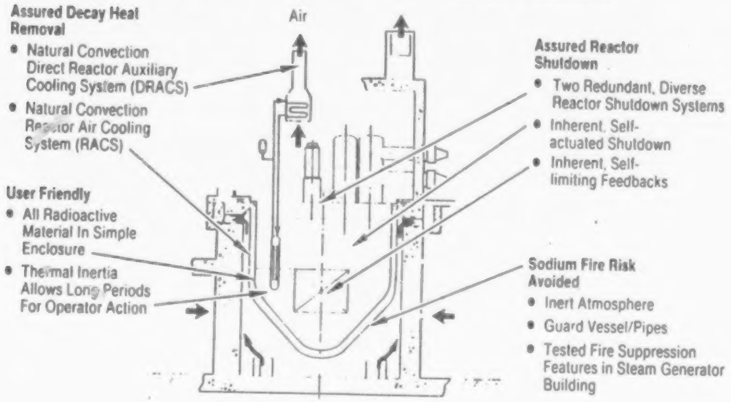

Assured Decay Heat Removal
• Natural Convection Direct Reactor Auxiliary Cooling System (DRACS)
• Natural Convection Reactor Air Cooling System (RACS)
Air
Assured Reactor Shutdown
• Two Redundant, Diverse Reactor Shutdown Systems
• Inherent, Self-actuated Shutdown
• Inherent, Self-limiting Feedbacks
User Friendly
• All Radioactive Material In Simple Enclosure
• Thermal Inertia Allows Long Periods For Operator Action
Sodium Fire Risk Avoided
• Inert Atmosphere
• Guard Vessel/Pipes
• Tested Fire Suppression Features in Steam Generator Building
4778-II-193

Figure 4. SAFR Safety Features

The SAFR shutdown system is composed of two reliable, independent, redundant, and diverse reactor shutdown systems. The primary system is similar to the Clinch River primary control rod design, and the secondary system is a self-actuated shutdown system (SASS) using a temperature-sensitive magnetic latch. Properly configured, SASS also serves as an ultimate security system which cannot be circumvented by saboteur action.

Reactor decay heat removal is ensured by two reliable, independent, redundant, and diverse passive systems that function in addition to the normal heat removal path through the intermediate and steam systems. The coolant is maintained at least 440°F below boiling by either of the two passive systems: one (the safety system) which removes heat by natural convection of air on the outside of the reactor containment vessel, and the other (the plant investment protection system) which removes heat through a natural draft sodium-to-air heat exchanger.

The number of systems and components on which plant nuclear safety depends has been minimized, and the balance-of-plant (BOP) and intermediate heat transfer systems have been decoupled from the safety systems. This means that BOP upsets will not affect nuclear safety and that the BOP and intermediate heat transfer system need only be constructed to high-quality commercial standards. In general, nuclear-grade field construction is limited (by minimizing safety systems and by maximizing factory fabrication and assembly) and physically segregated from the conventional high quality commercial construction used in other parts of the plant.

By utilizing passive, inherent safety features, plant costs are reduced significantly because of the elimination of complicated, expensive active safety systems. Eliminating these systems also increases plant availability by avoiding numerous potential sources of component failures.

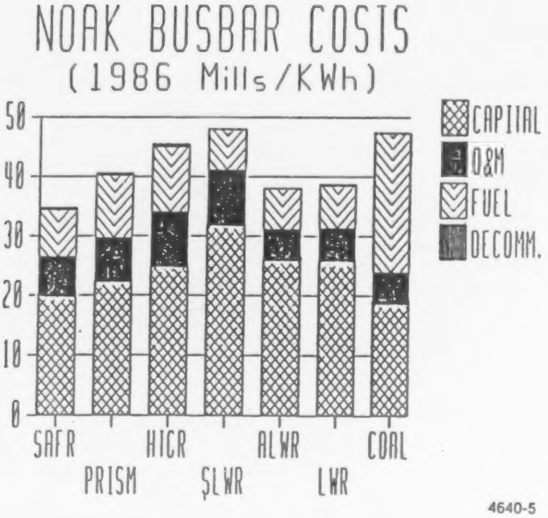
During the last 3 years, there has been an ongoing review of the SAFR design by the Nuclear Regulatory Commission. Thirty-one meetings have already taken place, focusing on the SAFR Preliminary Safety Information Document (PSID), and over 20 significant issues have been resolved favorably, enabling improvements in SAFR economics while maintaining assured safety. In addition, test and analytical results produced by various organizations working on DOE's LMR Base Program have substantiated many SAFR design features.

A probabilistic risk assessment (PRA) for SAFR shows that public risk due to release of radioactivity is orders of magnitude better (i.e., lower) than Nuclear Regulatory Commission (NRC) safety goals. These results provide encouragement that SAFR can be such an extremely low-risk plant that off-site evacuation plans will not require local governmental approval.

An inherently safe reactor should equate to easier licensing and increased public acceptance. Since SAFR will be a standardized plant design, obtaining construction and operating licenses will be faster and easier than has been the case in the past.

ECONOMICS

Continuing cost/benefit analyses of the SAFR design are helping to minimize plant capital and busbar costs, without compromising plant safety margins. An independent DOE Cost Estimate Review Panel has developed capital and busbar cost estimates for SAFR and other reactors during each of the last 3 years, and compares them to the costs of other power generating systems. The results of the last DOE study to be published (based on the 1986 350-MW SAFR design) are presented in Figure 5 and show that the SAFR costs are lowest.



4640-5

Figure 5. Estimated Busbar Costs of Different Power Plants (Nth-of-a-Kind Plants)

Since this cost study was made, the SAFR module power level has been increased nearly 30%, from 350 MWe to 450 MWe, with a resultant reduction of 16% in busbar power cost. This was done by increasing the size of the reactor core, reactor vessel, heat transfer system, pumps, and turbine generator while keeping the core power density and the primary and secondary system temperatures the same. This in turn allowed us to maintain (or even increase) all of the SAFR safety margins.

UTILITY NEEDS/ACCEPTANCE

As stated in the Introduction, SAFR's raison d'etre has always been to meet the needs of the utility industry for a new type of nuclear power plant. With this requirement always in mind, the SAFR design has now evolved to the point where it has a high level of acceptability with most U.S. utilities, and also with the Japanese.

During the evolution of the SAFR design, utility needs have been identified and addressed through design reviews and critiques by various review/advisory groups. The first of these to be established was the SAFR Institutional Advisory Committee, which is composed of executives from utilities and the EPRI, as well as other high-level representatives of the nuclear industry. This group met periodically to review the SAFR design; they provided guidance on meeting user needs as well as on regulatory, commercialization, and public acceptance issues.

To interact with the utilities at a more detailed level, a series of 15 utility seminars and special evaluations were carried out. These were attended by a large number of utility representatives, who provided input about the general design and more specifically about the operability, maintainability, inspectability, and refueling features which had to be designed into SAFR.

During the final year of the Conceptual Design program, a formal Utility Technical Review Committee was established. This committee is made up of engineering representatives from 12 utility companies plus the EPRI. This group has and continues to meet quarterly for all-day reviews of the various areas of the SAFR design. This group provided valuable feedback on design features which their companies seek in any nuclear power plant.

These reviews and meetings have been very beneficial. The utility industry has been informed and educated about the potentials of SAFR, and the SAFR design team has been developed to meet utility requirements. The results of this process suggests the SAFR concept can achieve a high level of acceptability. Utility representatives have indicated:

- SAFR's inherent safety is very attractive;
- The simplicity of the SAFR design is very appealing, especially the arrangement of the one reactor, one turbine power module;
- SAFR's choice of a superheated steam cycle was wise; and
- If SAFR's economic projections can be realized and the technical performance and licensability can be demonstrated, SAFR would be an acceptable, attractive power generation system.

The thrust to assure in detail that SAFR meets utility needs has been strengthened during the current Design Improvement phase by the addition of Duke to the design team. Duke will perform an independent review of the overall design; evaluate plant operation and maintenance characteristics; and assess capital, operating, and maintenance costs.

The Japanese interest in SAFR stems from their Demonstration Fast Breeder Reactor (DFBR) Program, which is scheduled for construction in the late 1990s. DFBR, a 1400-MWe pool-type LMR, has many features similar to those of SAFR. In fact, SAFR is referred to in Japan as the "little DFBR." By using the SAFR design as a synergistic complement to DFBR, it is anticipated that major Japanese financial commitments can be obtained for the design and construction phases of the Reference Advanced LMR Program. An additional benefit of JAPC support is enhanced technical and economic credibility.

POTENTIAL SPECIAL USES OF SAFR

In addition to offering an attractive potential power generation option for the utility industry, SAFR has features which make it uniquely adaptable as (1) a future breeder reactor, (2) a "burner" to dispose of long-lived transuranic wastes from spent light water reactor fuel elements, and (3) a military production reactor to generate tritium.

The nation's energy supply situation is such that the need for a breeder reactor is not expected to develop for over 20 years. However, when the need for a reliable nuclear power system which generates extra reactor fuel does arise, the SAFR design can easily be adapted to meet this need. The SAFR reactor core can be converted into a breeder core simply by replacing some of the shield assemblies with blanket assemblies. Also, if larger breeder reactors are needed, the simplicity of the SAFR design, and its similarity to existing large foreign breeder reactors, will make scale-up easy.

One of the tasks of the present SAFR Design Improvement program is to investigate the capabilities of the SAFR reactor to perform as a transuranic (TRU) waste burner, and thus eliminate these ultra-long-lived nuclear waste materials as waste disposal problems. A SAFR reactor, with its metal-fueled core, can provide excess neutrons which are available to transmute (by fission) the plutonium and other TRU elements which are present as waste in spent light water reactor fuel elements. In concept, a head-end electroreduction step can be integrated with the IFR electrorefining process to convert spent LWR fuel into a U-Pu metal phase which contains all of the other TRU material. This metal phase can then be made into SAFR fuel elements and used (and reused) in the SAFR reactor, thereby generating power while converting the TRU material into shorter-lived fission products. When developed, this process will make SAFR a very valuable adjunct to existing LWR power production.

With suitable lithium targets in their cores, LMRs in general and SAFR modules in particular can be very reliable and efficient tritium producers. This LMR application, and the target technology, is being studied by Argonne National Laboratory.

1504D/slw

Attachment 2

SPACE NUCLEAR POWER ADVANTAGES

- Can provide high power, long life with favorable mass and envelope
- Can accommodate high threat levels with minimum cost and weight impact
- Allows spacecraft orientation to be independent of power system
- Provides flexible integration of power system with spacecraft
- Small moment of inertia--reduces station keeping weight
- Eliminates array interference with sensors and antennas (shadowing)
- Compactness minimizes detectability
- Can withstand high maneuvering loads
- Allows rapid pointing and tracking of spacecraft (stiffness)
- Can operate without degradation in Van Allen belt
- Can supply thermal heat to electronics during "nonoperating" periods--eliminates large batteries
- Eliminates space plasma interactions at high voltages
- Minimizes aerodynamic drag at LEO
- Minimizes solar pressure disturbances on spacecraft
- Small power change over lifetime.

1507D/ljm

PANEL 2: DISCUSSION

Mr. STALLINGS. Thank you, Mr. Harris. Dr. Jones, what reason has DOE given for their decision to terminate the strategic technology programs in Fiscal Year 1989?

Dr. JONES. Mr. Chairman, we were mystified by that. I think it's a combination of budget constraints and other pressures. But when we discussed that issue, a high-level official in DOE told us that we would just buy that technology offshore.

I think, considering the fact that we've done an awful lot of work over many years on this technology, that doesn't make sense to us.

Mr. STALLINGS. Thank you. Mr. Berglund, where do you see the markets arising over the next three to five years for modularized light water reactors such as the advanced pressurized water reactor design which GE has been developing?

Mr. BERGLUND. I think I'd like to answer that in about three parts. First of all, we are not working on an advanced pressurized; we do have an advanced boiling water reactor. We have currently taken an order, together with Hitachi and Toshiba, in Japan for two systems on the Tokyo Electric Power System. So in terms of orders, the first two orders for that advanced system have already been taken.

With respect to this country, I don't see any orders in the next three to five years, and I don't see any until such time as we can give the user community, the utility community, some level of confidence through the regulatory process and the certification of designs, completed designs. Once we can establish that user confidence we can also work on the public acceptance issue.

Mr. STALLINGS. Thank you. Mr. Harris, I understand that operating costs at the Energy and Technology Engineering Center are being significantly defrayed through the operation of the Power Pak program. What percentage of the facility's operations are expected to be funded as a result from revenues from the Power Pak program?

Mr. HARRIS. I would say that the Power Pak project is nearing completion and will be undergoing acceptance tests this summer, and it's projected that when the Power Pak is fully operational and utilized in concert with major test articles that it would bring in revenue in the range of $12 to $14 million a year, which would basically defray about 50 percent of what would historically in the past have been budgeted DOE test numbers.

If you go back and look at historically what has been approved by this Committee in prior years, the ETEC budget was running close to $30 million a year. And with the Power Pak coming online, the agency requests are in the range of $12 to $13, and so you can see that the budgets have been discounted.

And the reason that Rockwell pursued the Power Pak initiate was there was a recognition that there were diminishing resources available for the Advanced Reactor Program. We were encouraged in earlier years by the agency to find some innovative ways to be able to continue to pursue the mission of testing advanced reactor components at reduced cost to the Government. We came up with a concept of a cogeneration facility called Power Pak by which we could sell the excess steam-generating electricity to a utility in

California, get the revenues back, offset the budget cost to the Department of Energy for testing the advanced reactor components.

Mr. STALLINGS. Thank you. Mr. Morrison?

Mr. MORRISON. Thank you, Mr. Chairman. I realize we're under some pressure because this room is in demand in about 35 minutes, so let me limit my questions, and in fact maybe more of a comment to both Mr. Berglund and Mr. Harris. It's refreshing to have both of you so enthusiastic about the liquid metal concept. We've been besieged a little here with our friends from the high temperature gas arena.

I sense both GE's PRISM concept and your SAFR concept are head to head, and I won't dare ask you which is preferable because somebody else will be making that judgment as time goes by. But really very pleased with the progress you're making, and I'm sure the Subcommittee will want to advance both of these technologies.

Mr. Frey, SP-100 yesterday certainly got some super marks from the folks that are customers of yours. Are you, as far as the corporation is concerned, aware of the importance of our getting funding for the Pathfinder program in order to continue with the testing of SP-100?

Mr. FREY. Yeah, I think so. I'm not personally close to the Pathfinder program but I understand it's an important part of providing future applications for the SP-100 program.

Mr. MORRISON. And future funding. I mean, for right now. That's going to be vital to us.

We are also pushing for an early mission for SP-100. Do you have any feelings on that potential? Any suggestions?

Mr. FREY. Well, I think finding a future mission is one of our most important goals in terms of protecting future funding. We're finding that the stewards of near-term operational programs seem to be unduly concerned with nuclear power in general, whether it be dynamic isotope or reactor power; we've seen that from Rockwell, we've seen that in the DIPS program, and we've certainly seen it in the reactor program. When you talk to people like Col. Casey at the Air Force Base Division or others who have responsibility for providing operational satellites on a near-term schedule, they're very wary of nuclear power.

While we would like to find, and we have some very active efforts to provide reactors in the 20, 30-kilowatt range to existing programs, I personally think the most promising aspects now are longer-range technology demonstrations in space which will give our users of the technology more confidence. One I mentioned in my testimony was the electric-propulsion area. I think electric propulsion is a very promising technology for interplanetary travel, as well as perhaps earth transfer orbits. It's an ideal demonstration program for SP-100, has some support from General Abrahamson in the SDIO, and I think that's a promising possibility.

But finding a mission is important if we're going to secure this program.

Mr. MORRISON. I think from a Congressional point of view, that certainly is true as well.

Mr. Chairman, I think I will forgo any questioning there because of time. Thank you.

Mr. STALLINGS. Thank you, Mr. Morrison. Gentlemen, we appreciate your testimony. I know the Chairman of the Committee has some serious questions that she will probably be submitting to you for some answers if you would not mind, and for the sake of time we will dispense with those and just have you respond in writing. Thank you.

[Questions and answers for the record for Dr. Jones and Mr. Harris follow:]

OAK RIDGE NATIONAL LABORATORY
OPERATED BY MARTIN MARIETTA ENERGY SYSTEMS, INC.

POST OFFICE BOX X
OAK RIDGE, TENNESSEE 37831

April 21, 1988

Honorable Marilyn Lloyd
Chairman, Subcommittee on
Energy Research and Development
Committee on Science, Space, and Technology
U.S. House of Representatives
Suite 2321, Rayburn House Office Building
Washington, D. C. 20515

Dear Mrs. Lloyd:

As requested in your letter of April 5, I am enclosing our response to questions for the record following my testimony on March 17 at the hearing on DOE's FY 1989 Authorization Request for Nuclear Fission.

I am pleased to have the opportunity to respond to the questions. Please let me know if you need any further information (FTS 624-4187).

Sincerely,

John E. Jones Jr.

John E. Jones Jr.
Director, Reactor Programs

JEJ:mho

Enclosure

CC: J. R. Merriman

Response to Questions for the Record for the Hearing of March 17, 1988 on DOE FY 1989 Authorization Request for Nuclear Fission Subcommittee on Energy Research and Development

by

John E. Jones Jr.
Director, Reactor Programs
Oak Ridge National Laboratory

Question 1. What is your total estimated cost and schedule of the strategic technologies initiative program?

Answer: Strategic technologies are ongoing technology development activities. Some of these activities have been ongoing for many years and are nearing completion of the present tasks. For example, (1) the JASPER shielding program is approximately two years from completion, and (2) the March 1988 Materials and Structures Technology Plan developed by ORNL in collaboration with GE, Rockwell, and DOE calls for completing the materials data and structural design methods and tools to qualify modified 9Cr-1Mo for nuclear application over a four-year period.

On the other hand, some of our efforts are at an early stage of development. For example, Advanced Control, Advanced Instrumentation, and Robotics fall in this category.

In the near-term, say over a 5-year planning horizon, we believe a stable $10 million per year level of effort in Strategic Technologies is sufficient to make significant progress in all these technologies and complete the present work in Shielding and Materials and Structural Design. The appropriate long-term program in Strategic Technologies will be influenced strongly by our success in moving forward with plans for demonstration of advanced reactors in this country. We will update these plans annually.

Question 2. It is recognized that you have requested $10 million for FY 1989. We are interested in your total our-year projections. How are these programs in strategic technology coordinated within the advanced liquid metal reactor R&D program; that is, how do you work with other laboratories and contractors? Is there an effective program to transfer these technologies to industry?

Answer: Our current projections for the Strategic Technology out-year budget are tabulated below. These will be updated annually as a normal part of our planning effort.

Strategic Technology Out-Year Budget Projections
for FY 1989 Through FY 1993 Based on Total of $10 Million
(in FY 1989 dollars)

	1989	1990	1991	1992	1993
Advanced Control/Automation	5.0	5.5	6.0	6.0	6.0
Advanced Instrumentation	1.0	1.0	1.0	1.0	1.0
Shielding	1.5	1.0	-	-	-
Materials and Structural Design	1.5	1.5	1.5	1.0	1.0
Robotics	1.0	1.0	1.5	2.0	2.0

How are these programs in strategic technology coordinated with the advanced liquid metal reactor R&D program; that is, how do you work with other laboratories and contractors? Each of the programs in Strategic Technologies has been coordinated with the two advanced LMR concept design teams headed by GE and Rockwell, as well as with DOE and other DOE contractors and laboratories. Specific mechanisms and relationships vary with the program area.

The Advanced Control program provides integration of controls technology in the DOE program. ORNL is coordinating directly with General Electric, Rockwell International, HEDL, and ANL to review their controls requirements and to propose technical approaches that take advantage of current research results. A utility advisory committee has reviewed the program to ensure that the work is of potential benefit to industry. A cooperative demonstration of some advanced control features proposed by ORNL at the EBR-II is being actively discussed.

In Advanced Instrumentation, ORNL's improved neutron flux monitoring system has been incorporated in both PRISM and SAFR concept designs. Rockwell estimates it will save $12 million per SAFR plant. ORNL's automated noise diagnostics system is undergoing prototype testing in the Fast Flux Test Facility in Hanford.

The ORNL Materials and Structures Technology Plan was prepared in collaboration with GE, RI, and DOE, and is directly responsive to the most urgent of the designers' needs.

The Robotics program is a team effort led by ORNL and involving four major universities and their respective industrial partners:

University of Florida, Odetics
University of Michigan
University of Tennessee, Combustion Engineering, Remotec
University of Texas, Martin Marietta Aerospace

Advanced concept designers and utilities are helping to provide guidance to the Robotics program along with a Board of Governors which has been established by the team to provide oversight and guidance.

The Shielding program is coordinated extensively with PNC of Japan because they are a major sponsor, along with DOE, of the Japanese/American Shielding Program of Experimental Research (JASPER) program. Design support in shielding, based on the advanced materials and methods derived from the JASPER program, is provided to the PRISM (GE), SAFR (Rockwell), and MHTGR (GA). The advanced concept designers are using this information directly to improve their designs. For example, GE estimates a capital cost savings of $20 million per plant for the PRISM concept is directly attributable to the use of advanced B_4C shielding material based on our technology. DOE has an extensive analytical capability in shielding design codes, models, and methods at ORNL which is not duplicated at other laboratories and contractors. This expertise is made available to all advanced concept designers through the Strategic Technologies program.

Is there an effective program to transfer these technologies to industry? Overall, Martin Marietta Energy Systems has established the most effective and aggressive technology transfer program within the DOE contractor family. We are very proud of this accomplishment and are continuing to build on our success to date.

Strategic Technologies are applied technologies, not basic research. Our purpose is to advance the state-of-the-art in reactor technology and to enhance the safety and economic competitiveness of advanced concepts. This work is meaningless unless it leads to implementation of strategic technology advancements in emerging advanced concept designs. Therefore, we take our responsibility for technology transfer very seriously.

In Advanced Control, the philosophy of our program is to build a workstation environment for support of industry design of fault-tolerant, hierarchical digital control and to provide tools, models, and methods, as well as prototypic software, to support the design of advanced digital control systems. In addition, we expect to contribute to industry guidelines and standards and to provide a means for validation of advanced control software and systems through a real-time simulator capability. In short, the entire thrust of our program is to provide the most efficient and effective means to transfer advanced control and automation technology to the nuclear industry.

Advanced Instrumentation is developed in collaboration with designers and in support of their needs. For example, the improved flux monitoring system under development at ORNL has been adopted by both GE and RI. Technology transfer is a natural outflow of these collaborative development processes.

In Materials and Structural Design, the modified 9Cr-1Mo steel developed by ORNL is a major advance in high-temperature structural materials. This material is already incorporated in ASME Section I and Section VII, and is now commercially available from several manufacturers. (This has already been a major technology transfer success.) The material is now in use in many fossil power plants and in other high-temperature applications. Additional materials data and structural design methods are being developed within the current plan to complete the information necessary to qualify the material for nuclear application, ASME Section III. Advanced reactor designers are fully aware and strongly supportive of this effort. They are currently using the material in their conceptual designs based on the expectation that this work will be completed.

Shielding is an area where much of the analysis is done in-house at ORNL for all advanced reactor concepts and provided to designers. This is not because of a lack of enthusiasm on our part to transfer the technology and methodology, but rather that the level of effort and expertise required to perform the analysis is such that multiple capabilities are not justified at this time. In this case, technology transfer takes the form of analytical support of advanced concept designers.

Robotics technology for surveillance and maintenance in advanced reactor systems is at an early stage of development. Excellent lines of communication are in place to implement technology transfer as the program progresses. The team effort involving university and industry partners is an outstanding mechanism to assure technology transfer.

Question 3. As you know, the Department of Energy has made the decision to move to metal fuels in the liquid metal reactor program. As Oak Ridge was commonly involved in the technology associated with the oxide fuel program, what impact has this decision had on the laboratory capability in nuclear fuels?

Answer: Although the DOE has moved toward metal fuels in the liquid metal reactor program, a significant element of the DOE program remains completion of the oxide reprocessing development program at ORNL. This proved possible because of a major collaboration worked out with Japan which is providing $5 million per year for five years (through 1992) in support of that program. DOE is contributing an equal amount. A major part of this program focuses on remote technology, which is also applicable to the metal fuel cycle. This will retain the capabilities in that area at ORNL for that time period.

The technical staff at ORNL provided limited support last year to the ANL metal fuel cycle program for an equipment concept. Some planning was also done with ANL to examine the remote technology aspects of the ANL concept, but no funds were made available this year to ORNL to continue work in either area. ANL is presently concentrating on a small-scale engineering test in the existing facilities. Ultimately, major developments of remote technology equipment will be required, to which we hope to contribute our expertise in this field.

Question 4. Do you think that the FY-1989 budget strikes an adequate balance between funding for (technology) programs versus funding for facilities in the Advanced Reactor R&D program?

Answer. The direct answer to this question is **NO!** Technology programs are abandoned in this Budget Submission in order to retain funding for facilities.

Technology is the foundation of the Advanced Reactor Program, without which the U.S. can have no commercially viable advanced reactor concept. This is clearly recognized in program plans for advanced concepts. For example, a draft Liquid Metal Reactor Program Plan was completed in November 1987 following two years of intensive planning effort. The overall strategy is summarized in the plan as follows:

> "The LMR program strategy consists of four main parts. The first is to *complete an advanced conceptual design of a licensable, economically competitive reference LMR plant* that incorporates passive safety and environmentally acceptable features in the reactor plant and fuel cycle.
>
> "The second part is to *develop and demonstrate metal fuel, including closing the fuel cycle, while maintaining oxide fuel as a backup.*
>
> "The third part of the strategy is to *perform technology development R&D to verify component and system reliability and eliminate performance uncertainties in both the reference concept design and fuel cycle.*
>
> "The fourth part of the strategy is to *provide facility test capabilities and the technical expertise at national laboratories and test centers that are required by the LMR program.* These facilities — designed, constructed, and operated by the national laboratories and prime contractors for government — will develop and demonstrate safety and performance technologies that eliminate or minimize technical and economic uncertainties to private sector deployment of advanced LMR reactors and fuel cycles."

A balanced program is essential if any real progress is to be made. The purpose of facilities is to "**demonstrate** safety and performance **technologies** that eliminate or minimize technical and economic uncertainties ..." If the technology programs identified in the third part of the strategy are abandoned, the facilities cannot accomplish their mission.

Question 5. What is the goal of your 5-year program plan to enhance operator's understanding and management of the entire system. Is this a "universal" program applicable to LWR, LMR, and HTGR?

Answer: The purpose of the Advanced Controls program is to conduct research and to provide technical leadership in the design, testing, and validation of advanced, automated control systems that would provide improved operability, reliability, and safety for advanced reactor systems. In order for these efforts to be successful, consideration must be given, and is being given, to all system elements including the human operator. Just as technological advancement has allowed hardware and software improvements, so too can attention to the role of the operator in the evolving advanced control system designs achieve similar results. The ORNL program in advanced controls addresses not only the technological development of advanced control hardware and software, but considers, simultaneously, the interfaces that such elements have on the performance of the human operator.

Efficient reactor operation relies on a well-defined role for the human operator. For advanced control systems, this role is significantly different from the current role held by the human operator in nuclear power plants, and deals with the specification of different levels of operator responsibility and authority. A greater focus must be directed, and is being directed, toward the design of interfaces that promote: (1) enhanced operator understanding of system status, and (2) effective operator conceptualization of system operation. The specific goals of the long-term advanced controls program plan regarding operator understanding and facility management are focused in three areas: (1) operator role definition, (2) functional allocation, and (3) control and display requirements.

With regard to the "universality" of the program, the advanced controls program is directly supportive of LMR designs; however, the principles and knowledge gained from the research is applicable to other reactor concepts. We expect to broaden the program scope in FY 1989 to begin work which is directly supportive of Advanced LWR designs as well. In general, Strategic Technologies can contribute to the inherent safety and international competitiveness of all U.S. advanced reactor concepts.

Question 6: How advanced is the HTGR technology in foreign countries compared to that in the U.S.? Germany (FRG) invests a sizable amount ($75 million/year) in HTGR technology and has a cooperative agreement with us for 10 years. What have we learned from each other?

Answer: The United States has an extensive and structured program in HTGR technology development. The FRG has carried out in-depth development and testing in specific areas. Japan has more of an embryo program to date, with emphasis on component testing in their HENDL facility. Relative to FRG, the United States is more advanced in MHTGR design, in the planning of base technology development, and in

MHTGR licensing interactions. FRG is more advanced in the technology development of MHTGR-type fuel elements and in mechanical property information on advanced HTGR materials. Relative to Japan, the United States has a broader and more extensive base technology program, but Japan is initiating and expanding important work in technology development. The United States has a much stronger MHTGR design effort than does Japan, while Japan emphasizes the design of a 30 MW(t) high-temperature test reactor which is to begin construction in 1989. To date, the United States and FRG have benefitted very significantly by their cooperation. The cooperation with Japan is less than three years old, and in-depth cooperation is just now beginning, so the learning process has not proceeded very far.

With regard to what we have learned from the U.S./FRG cooperation, the United States has obtained key fuel performance information regarding the inherent safety of MHTGRs. FRG has developed, fabricated, and fully tested FRG MHTGR fuel elements; their favorable results on fuel performance gives the U.S. high confidence that the inherent safety of MHTGRs is achievable. FRG has also contributed to the development of U.S. fuel performance models. Graphite irradiation creep behavior under tension has been obtained from FRG, useful in understanding reactor graphite behavior. Also, FRG has an extensive advanced HTGR materials program for high-temperature process heat systems, and the knowledge and understanding of gas-metal interactions/mechanisms in HTGR helium has been very useful to the U.S. For its part, FRG has benefitted from the extensive planning carried out in the United States relative to determining the key technology development needs for MHTGR development. The U.S. has also provided FRG with (1) fuel performance models for MHTGR coated particles; (2) specific and unique performance testing evaluations of FRG fuel, including performance assessment of reference fuel for the Thorium High-Temperature Reactor; (3) irradiation creep data on graphite under compression which is useful for estimating reactor graphite behavior; and (4) knowledge concerning the thermal stability of high-temperature materials.

Under the U.S./FRG HTGR Cooperation, about ten U.S. technologists have been assigned to work in FRG for a period of about a year, and similar assignments have taken place from FRG to the U.S. These personnel exchanges have facilitated transfer of technical information useful to both sides. During prior years, there has also been cooperation in HTGR fuel recycle technology, with emphasis on head-in treatment of the fuel, reprocessing, and refabrication development; a joint design was developed for an HTGR spent-fuel treatment facility.

From our interactions with Japan, the United States has learned that both sides can benefit through planned, close cooperation in base technology development involving the fuel, fission products behavior, graphite and metals areas. At present, an extensive HTGR fuel test program is being carried out in the U.S. with joint funding to obtain detailed information on fuel performance under various conditions. Irradiation of U.S. and Japan HTGR fuels will begin this year. Specific test plans in the graphite area have been prepared and are being implemented. Test plans in metal technology development are presently being prepared.

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April 27, 1988

In reply, please refer to 88RC05178

The Honorable Marilyn Lloyd, Chairman
Subcommittee on Energy Research and Development
Committee on Science, Space, and Technology
U.S. House of Representatives
Suite 2321 Rayburn House Office Building
Washington, D.C. 20515

Dear Chairman Lloyd:

The answers to the questions transmitted by your letter of April 5 are attached. We appreciated the opportunity to testify before your subcommittee on the important nuclear power programs concerned, and hope the attached answers meet your needs. If you have any other questions, we will be happy to respond.

Very truly yours,

ROCKWELL INTERNATIONAL
ROCKETDYNE DIVISION

D. C. Gibbs
Division Director
Atomics International

DCG/sjs

Enclosure

A. QUESTIONS FOR THE RECORD

1. QUESTION

What is the funding level in FY 1988 and what are the projected funding levels in FY 1989? Do you deem these funding levels to be adequate for the work required?

1. ANSWER

The funding levels for the 3 areas covered by the testimony are:

(1) Liquid Metal Reactor Development

Calendar Year 1988 funding level is $5.7 million. Projected FY 1989 funding level depends upon the SAFR design being selected as the Reference Advanced LMR. If this happens, the projected funding level for FY 1989 is approximately $12 million. These funds would be adequate for the work we proposed to do in the first year of the Reference Advanced LMR Program, and will keep the LMR development program on a schedule compatible with the DOE LMR Program Plan.

(2) Space Nuclear Power

The FY 1988 funding for the Dynamic Isotope power Subsystem (DIPS) ground demonstration program is approximately $10 million. $41.5 million is required in FY 1989 to perform the engineering and testing defined in the DOE plan that leads to qualification of this enabling technology by 1992. Projected funding for FY 1989, however, is $21 million, the minimum amount to maintain a contractor team making reasonable progress toward flight readiness. This amount permits design, fabrication and component tests as a basis for a full DIPS ground demonstration in 1992, but precludes qualification of a specific flight configuration before about 1994. This may delay vital military satellites should evolving survivability requirements dictate the need for DIPS, as expected by many planners.

The Multimegawatt (MMW) power system program is necessary to form the foundation for defining possible approaches to spacecraft in the next century. Presently, uncertainty in the technology, system characteristics, and development lead time prevent all but the most conceptual planning for missions requiring very high steady or burst power. The planned program to spend $3 million in FY 1988 on six alternatives and $15 million in FY 1989 on the most promising is the minimum to adequately begin the formation of a sound planning base.

No funding is currently projected, as recommended by the AF/DOE Evaluation Panel for Small Space Reactor Systems, to "carefully review" a SNAP reactor/Brayton cycle power system as a backup to SP-100. They recommend "design studies.....to define the exact configuration and to determine what would be required to produce every component...to ensure that this system is really available to be deployed in no longer than a few years." Approximately $0.5 million in FY 1989 would provide this assurance and a planning basis for early flight of a nuclear reactor system. An early flight of a low risk system may prove valuable to the overall nuclear space power program (i.e., SP-100, MMW, DIPS).

(3) ETEC

FY 1988 funding level is $11.47 million. Projected FY 89 funding level is $10.9 million. The funding levels for each year are insufficient, and many high priority LMR R&D activities have been either cancelled or postponed.

2. **QUESTION**

Do you think that FY89 budget strikes an adequate balance between funding for programs versus funding for facilities in the Advanced Reactor R&D program?

2. **ANSWER**

The problem with the FY 89 budget is not the imbalance between funding for programs and funding for facilities; instead it is the inadequacy of the overall budget. The budgets for the various facilities have been cut back to the bare minimums needed to keep them operating, and yet the total budget is so small that these (actually inadequate) facilities budgets make up a large percentage, and hence, the budget may seem imbalanced. Many of the facilities are being very innovative in cutting costs (such as ETEC's use of cogeneration to reduce test costs) and seeking additional customers and this should be encouraged. However a bigger total budget is needed to achieve a more balanced reactor development program and in turn make better use of the facilities.

B. **REPUBLICAN MEMBER QUESTIONS**

1. **QUESTION**

The SAFR design has received many favorable reviews, and the licensability looks promising. Can you comment on it's economic compatibility with other alternatives (such as coal) of the same size?

1. **ANSWER**

The Department of Energy has conducted annual economic evaluation of the SAFR power system for the last 3 years. These evaluations are for one-module and four-module SAFR plants (450 MWe and 1800 MWe) and they are compared with economic projections for large power plants using competing technologies (coal and LWRs). The last results which have been published (based on the 1986 study) predicted that SAFR would have the lowest busbar electricity costs of all the options studied, including coal, advanced light water reactors, and other advanced reactors. We are continuing our efforts to make SAFR even more economical, with promising results, and our new SAFR team member, Duke Engineering and Services, Inc., will also evaluate SAFR cost projections to make them as accurate as possible.

2. **QUESTION**

The ETEC facility is taking on many activities recently; and yet over the last 10 years, staff level was reduced by 65%. At this level can ETEC operate safely and effectively?

2. **ANSWER**

The ETEC budget and staff reductions have not impacted safety or effectiveness, but have caused delays and cancellations of important programs.

ETEC always makes Safety a high priority. To assure this, ETEC procedures require that all aspects of safety are considered from a program's inception to completion. When appropriate, a complete Safety Analysis Report

(SAR) is prepared. This document is reviewed by senior management and DOE. The periodic safety audits conducted both internally and by DOE-SAN have found ETEC to be in compliance with these procedures. And "on the bottom line", ETEC's safety record continues to be excellent.

ETEC has been able to maintain its effectiveness through numerous steps that have reduced or minimized cost without jeopardizing efficiency. For example, ETEC has developed an economical system for putting temporarily unused test facilities in layup and maintaining them at very modest cost ($1-$15/hour). The facilities are reactivating when needed with minimal startup costs. Facilities are normally not operated unless multiple tests are scheduled. Operating crews are not assigned to a single test facility and are reassigned at minimal cost impact as conditions demand. This gives ETEC considerable flexibility and allows effective and efficient operation. Many other factors - such as actions taken to reduce overhead - have also contributed to effective operation. A major step in increasing ETEC's effectiveness even more will be the addition of the Power Pak cogenerator to the SCTI facility in late FY 1988. The income derived from the sale of electricity will greatly offset test costs.

On the negative side, due to budget constrictions, important R&D programs have been stopped or indefinitely postponed. These programs are of such a priority that they must be completed at some time to support a safe, low cost, licensable, and reliable LMR plant.

PANEL 3: UNIVERSITY NUCLEAR ENGINEERING PROGRAMS

Mr. **Stallings**. Our third panel comes from the education community. Gentlemen, if you would please be seated. Presenting testimony first will be Professor Edward Klevans, the Chairman of the Nuclear Engineering Department at Pennsylvania State University; he will be followed by Professor Thomas G. Williamson, Chairman of the Nuclear Engineering Department at University of Virginia. Gentlemen, your written statements will be made part of the record in their entirety.

We also have Professor R.C. Gonzalez, Electrical and Computer Engineering, from the University of Tennessee. We are pleased with this panel. Dr. Klevans, if you would like to begin.

Let me just note that we do have to be out of here around noon, so if you could summarize and be brief in any way possible, your full testimony will be included in the record.

STATEMENT OF DR. EDWARD H. KLEVANS, PROFESSOR AND DEPARTMENT HEAD, COLLEGE OF ENGINEERING, NUCLEAR ENGINEERING DEPARTMENT, THE PENNSYLVANIA STATE UNIVERSITY, UNIVERSITY PARK, PA

Dr. **Klevans**. Thank you, Mr. Stallings. That's what I will do. I want to summarize key points from my prepared remarks and make some additional comments not included in those.

The three key points that I want to hit on are first that there is a very serious need for a Department of Energy/university technology base program to support nuclear reactor technology research. This program I believe should be funded in Energy Research rather than in the Office of Nuclear Energy. Historically over the years, the Office of Nuclear Energy has not had a commitment to a base technology program and they have not considered that part of their mission. The only base-funded program, or the only continuous-funded program for a number of years out of the Office of Nuclear Energy has been a small pass-through program related to the liquid metals program.

In 1985, a new initiative was begun to provide for a base technology program. I have described that in my remarks in my testimony.

However, I would comment that because of limited funding, a total of 17 projects related to nuclear energy programs was begun, and funding problems arose already in the third year of that program when no new funding was added and only carryover money was used to support the programs.

In the 1988 year, when a number of us, including Penn State, were in the second year of what was anticipated to be a two-year funded program, we found ourselves in a very serious situation where we did not know where the money was going to come from because Congress had not acted on the budget by October 1, and we did not know whether the commitment was going to be there for funding for second year. We continued to support our students and faculty on this project; we thought it was important, the students needed to continue in this vein. We expended $30,000 of our money which was recovered, I might add—before the funding was provided out of the $5 million new initiative that was passed by Congress, for which we are quite grateful.

I believe that because of this absence of a true commitment to this kind of a program by the Office of Nuclear Energy that the appropriate to fund this work is through the Energy Research Office, which does support and is accustomed to supporting university-based programs.

The second comment that I would like to make is that we are in dire need of continuity of funding for this program. I already discussed the problems that we ran into with a lack of continuity, of clear continuity, of the program for funding in FY 1988. The new program, the new initiative of $5 million which began in FY '88 and is being administered by Energy Research, does not have funds contained in the FY 1989 budget to continue this initiative.

This presents us once again with the startup of an estimated 15 new projects with about $2 million devoted to them and not being able to continue these into a multi-year cycle in a meaningful way. This is very disruptive and provides enormous difficulty for us in planning for the use of our programs and for bringing in new students.

So we would urge you to correct this situation, to provide for funding in the FY 1989 budget. It's my understanding that the FY 1990 budget does include money for this initiative, and what we need is to have 1989 money.

The third key point that I would make is that there has to be a higher level of support than exists in the current program. This initiative will include about $2 million for new startups which will, as I mentioned, provide for 15 projects, an estimated 15 projects, in the $100,000 to $250,000 range.

There are seven different areas being covered by this program. I am in support of the seven designated areas that have been formulated for support in this program. However, to have only 15 projects in seven areas, there is a mismatch here. We have, in addition, 26 nuclear engineering programs, 30 programs that I am aware of that are quite active in nuclear engineering, either graduate programs or nuclear engineering departments. All of these are going to be bidding very heavily for the available $2 million.

In my own Nuclear Engineering Department, I am aware that the faculty have been very excited about this whole prospect. Five different groups of faculty are preparing proposals in five different areas out of those seven areas. I know that there will be many, many very good projects proposed which will not be funded.

My estimate is that there is a need to support about 40 projects in these seven areas. This would require a level of funding of about $6 million in competitive grants and projects.

I would also like to comment on the pass-through program which has been administered through the Office of Nuclear Energy. I do believe, although the projects have been small, that that has been a successful program and that it is important to encourage academic participation and involvement with the National Laboratory programs and the programs such as you heard the previous panelists discuss. Therefore, I would urge the continuation of a pass-through program for academic research at the level of about $2 million.

This past year, the pass-through program for liquid metal research was at the $1.1 million level, down from the previous year, but that program is zeroed out for next year, and I think that that will be unfortunate.

I have concentrated my remarks on the research needs for nuclear engineering's future and the need—and let me say even the survival—of nuclear engineering education. I wanted to defer to Dr. Williamson for remarks on fellowships and reactor support programs and merely conclude my remarks on research needs by saying that it is my contention that the survival of nuclear engineering education requires that departments have strong research and graduate programs.

I served as an Associate Dean of Engineering for four years, and I can tell you that the Dean's Office takes a very hard look at the expensive programs that exist in the college, particularly programs such as nuclear engineering, which, to my knowledge, in every institution is about the most expensive engineering operation that we have. This is especially true if we have a nuclear reactor, which is a very expensive thing to maintain.

If there is not a solid base of support and a strong graduate program, Deans of Engineering are taking a very hard look at the existence of these programs, and that is one of the reason that there has been a decline in the past few years in the number of such nuclear engineering programs in nuclear engineering departments.

It is a critical issue for us, and I hope that we'll have your support.

Mr. Stallings. Thank you very much, Professor Klevans.

[The prepared statement of Professor Klevans follows:]

TESTIMONY TO THE SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT, COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY, U.S. HOUSE OF REPRESENTATIVES

MARCH 17, 1988

Edward H. Klevans
Professor and Department Head
Nuclear Engineering Department
The Pennsylvania State University

Good morning, Madam Chairman, Distinguished members of the Committee. My name is Edward Klevans. I am Head of the Nuclear Engineering Department at the Pennsylvania State University. Penn State has, for the past several years, produced between 9 and 10 percent of the undergraduate nuclear engineering degrees in the nation, making us the largest undergraduate department in the country. The current enrollment is 100 juniors and seniors. We are also responsible for 3 to 4 percent of the graduate degrees each year. At present we have 40 graduate students. The Department has approximately $600,000 in grants and contracts which support twenty-five of these students.

Penn State, along with the other nuclear engineering departments and programs in the nation, is helping to meet the need for talented nuclear engineers. Without such graduates it will be difficult to maintain safe, efficient, and economical operation of the one hundred nuclear reactors operating in the United States, or to develop the technology for future uses of nuclear energy. Our students are currently finding jobs in both commercial and military nuclear programs; and the demand is expected to continue. But will we continue to have healthy nuclear engineering departments that attract high quality students? This is a concern shared by all nuclear engineering departments. One of the factors that will determine our future is the availability of research funding to support graduate programs. Without adequate funding and the existence of exciting research projects, programs will not attract outstanding new faculty or graduate students, nor will we be able to obtain administrative backing in our own institutions. This last point is significant, for the number of Nuclear Engineering departments has been decreasing. There are now only twenty-six departments of nuclear engineering in the nation and fourteen programs housed in other academic departments. If nuclear engineering enrollments are not large enough and graduate programs are weak, Deans of Engineering have little incentive to maintain such costly programs.

Where do Nuclear Engineering Departments get research funding? One might expect that the Department of Energy would be a primary source of funds for university research into advanced nuclear reactor technologies. Until 1985, however, the only program that existed was a small program for research in liquid metal reactors. The universities received their grants from the prime liquid metal reactor contractors. In FY 1988 this program has $1.13 million, but there is no funding for FY 1989.

The major breakthrough for nuclear engineering research came in FY 1985 when the DOE Office of Nuclear Energy started a new initiative to fund university research in advanced technologies relevant to nuclear energy. In FY 1986 the funding was at the $1.75 million dollar level with an additional $1.35 million for a robotics initiative. During FY 1985 seven projects were funded and in FY 1986 eleven additional nuclear engineering and four robotics projects were funded. Continuation funds were used in FY 1987 to support the above projects, but new funds were not added. This number of projects is too small to meet the needs of the nuclear engineering programs. Too many outstanding proposals were not funded.

I want to share with you some of Penn State's experience with this program. We obtained funding at the beginning of FY 1987 to study an "Ultra-safe" light water reactor concept. The program was designed as a two year study. Three graduate students, an undergraduate student, two faculty members, and an emeritus faculty member participated in the first year effort. The funding for the first year was $125,000. Substantial progress was made on our project, and enormous creativity, excitement, and intellectual energy was generated in the process. Hopefully, a real contribution to the advanced reactor field is also being achieved.

The Penn State project was one of seventeen (including the four robotics projects) which expected to receive FY 1988 funding. When Congress did not pass the FY 1988 budget prior to October 1, 1987 we were faced with cutting off our research or continuing it using our own very limited resources and hoping that funding would become available when the budget was finally passed. You cannot take three students and simply cut them off in the middle of their research so we continued supporting them. I will tell you honestly that if Congress had not passed the $5 million appropriation for the 1988 DOE Nuclear Engineering Research Program (which is supporting our second year work, albeit at a reduced level), the effect on our Department budget would have been devastating. Academic departments simply cannot operate in an environment where their programs, particularly major programs, are simply cut off in the middle. It is disruptive for students and faculty, and it makes planning for current and future students very difficult. Continuity of funding is a critical element for any program.

The problem this year was not just with DOE. Budget cuts hit most research agencies. A radiation damage project that two of our faculty had with a defense agency was terminated (i.e., not renewed) because of budget cuts. The sponsor was very pleased with our work and is trying to locate funds to restart the effort. In the meantime the loss of funds has sidetracked a student's Ph.D. research. I have also been informed that my own DOE fusion research project will not be renewed in FY 1988 because of budget cuts. I am trying to find other funds to support my Ph.D. student.

This is the reality we face in trying to maintain strong research and graduate programs in nuclear engineering. In my department there is a very good faculty team doing reactor safety research. This is the kind of work which is funded by the Nuclear Regulatory Commission. But this year the NRC took very large budget cuts in research, so the anticipated startup of new university research projects never happened. Indeed, cuts, not startups, became the byword. Similarly, a new NSF initiative to fund nuclear engineering research was "postponed" when the final NSF budget turned out to be much smaller than expected.

Nuclear Engineering departments get their research funding from a variety of sources, including DOD, NSF, DOE, NRC and industry. Some of the departments have become basically applied physics departments because there has been no reliable source of funding for nuclear engineering research. Unfortunately, at this time each of the funding sources is under great fiscal pressure and in many cases university research is being cut.

The new $5 million DOE initiative which Congress passed for FY 1988 has great importance for nuclear engineering research and I want to express my appreciation for its passage. However, problems remain. First, the DOE budget does not provide continuity funding for FY 1989. Because of the timing in the passage of the new funding initiative, no request for second year funding was included in DOE's budget submission. With the zero budget for the liquid metal reactor university program and for the robotics program in FY 1989, we are potentially in the most disasterous position we have faced yet, the total loss of new funding in FY 1989. As I have indicated this would be very harmful to nuclear engineering research and education.

The second problem is that there is not enough money in the FY 1988 initiative to support needed research activities. Again let me use the Penn State situation as an example. My department expects to have four or five high quality proposals to submit to DOE by the submission deadline for FY 1988 funds. But only $2.1 million will be available for new starts. There will be a large number of high quality, relevant proposals submitted but only a small number will be funded. At least $6 million is needed for direct research funding. This would fund approximately 40 projects in the range $100,000 to $250,000 per year. Since many of the projects involve two or three faculty members the larger grants are needed. Finally, there is a need to maintain the national laboratory pass-through program, but to broaden it beyond liquid metal reactor research. The program would provide for academic research that is in direct support of the national laboratory reactor research activities. An additional $2 million is highly desirable to encourage this type of cooperative effort between the national laboratories and the universities.

When the research needs are added to the needs for graduate fellowships, traineeships, and reactor support programs, as discussed by Dr. Thomas Williamson, a $14 million request for FY 1989 is the appropriate level of support.

I have focused my remarks on the issue of research funding. This is not to minimize the importance of graduate fellowships or educational support programs; rather I have deferred to my colleague Dr. Thomas Williamson to discuss those areas.

Thank you for giving me the opportunity to express my views.

Mr. STALLINGS. Professor Williamson?

STATEMENT OF DR. THOMAS G. WILLIAMSON, CHAIRMAN, NUCLEAR ENGINEERING DEPARTMENT HEADS ORGANIZATION, AND CHAIRMAN, DEPARTMENT OF NUCLEAR ENGINEERING AND ENGINEERING PHYSICS, UNIVERSITY OF VIRGINIA, CHARLOTTESVILLE, VA

Dr. WILLIAMSON. Good morning. I am Chairman of the Nuclear Engineering Department Heads Organization, which represents the academic departments and programs in the country. This community consists of about 40 programs in 29 States; 26 of these departments offer accredited degrees in nuclear engineering and include representation of the top engineering schools in the country.

We are grateful to Congress for the support of nuclear engineering education by appropriating $5 million in the 1988 DOE budget for research and fellowships. I believe the funds serve a real need and will be wisely administered in a timely fashion. There are programs in place now to allocate these funds as follows: approximately $2 million for the new research initiative, $1 million for continuation of research begun in previous years, $.75 million for new fellowships, and smaller amounts for other programs including support of research reactors.

Let me talk about the fellowship program for a moment. If nuclear power is to remain a viable energy option, a workforce of nuclear energy professionals must be available. Vigorous program support for graduate students, such as the fellowship program, will have a major beneficial effect on enrollments and the supply of nuclear professionals.

Enrollments in nuclear engineering graduate programs have decreased by 35 percent from a high of about 2000 students in 1975 to about 1300 enrolled in 1986. In the decade of the 1980s, the number of Ph.D's awarded has decreased by 9 percent from 120; the number of Bachelor's and Master's degrees each decreased by 17 percent. The percentage of Ph.D's awarded to foreign nationals in 1986 was 53. This Ph.D. production is particularly troubling, since many of the foreign nationals return to their own countries, and the number of Ph.D. graduates available to U.S. employers, including the universities and the Federal National Laboratories, is declining.

The need of the universities is particularly troubling, since 65 percent of the faculties for nuclear engineering departments are senior professors, and only 14 percent assistant professors. Many faculty members, like myself, started teaching in the late 1950's and early 1960s, and we're looking forward to retirement. The universities will soon be looking for bright, young engineers to teach the next generation.

DOE and its predecessors have had a fellowship program that was stopped in 1976. It was reinstated in 1982, and in the present academic year, there are 20 fellows in the universities. With the funds appropriated by Congress in 1987, ten additional nuclear engineering and health physics fellowships will be started in 1988.

The panel is now reviewing the applications for next year, and I understand that there are 57 student applications for the fellowships to be awarded in 1988. Almost half of the applicants have grade point averages above 3.6.

As a further indication of the quality of the applications to this program, in 1986 there were 12 students named as "Honorable Mention" of which three were awarded fellowships. The average grade point of this "Honorable Mention" pool was 3.72. This is a truly talented applicant pool, and it's a shame that they could not all be funded.

I am proud that one of the three fellows appointed last year, John Hannon, is at the University of Virginia, and John is in the room with us today. John has an interesting background. He spent 20 years in the Air Force as an Electronics Tech. He went to the University of South Carolina to earn a physics degree, and he is now a second-year graduate student in nuclear engineering at our school. John and several of the students are here to give me support and to see how the professor stands up under a different setting.

This fellowship program has been successful in meeting the goal of providing engineers for the energy program. In the four years of the present fellowship program, there have been 35 graduates; 22 of these graduates are either employed by the Department of Energy or a DOE contractor, and four are employed by universities. All but one of these graduates are working in an energy-related occupation. This indicates the direct benefits to the country from the fellowship program.

We believe the fellowship program should be expanded. We believe we could accommodate as many as 45 fellows and trainees at a cost of $3 million.

The research aspects have been covered very well by Professor Klevans. I just want to point out that the 1988 research initiative is funded at approximately $2 million, and this program was announced on March 4. It is being administered by DOE through the Idaho National Engineering Laboratory and is now in the process of accepting proposals. It will probably fund between 10 and 20 research projects for two years each. With approximately 30 major nuclear engineering departments, 300 faculty, and 1300 graduate students, the program will only reach a few.

From the phone calls I have had in the past several weeks as Chairman of NEDHO, I am convinced that DOE will be overwhelmed. I expect at least a half a dozen from my faculty; Ed said he's going to have at least a half a dozen from his faculty. That's a dozen from two of the many schools.

We believe the program should be tripled to $6 million in the 1989 budget.

And finally, let me talk a moment about research reactors. Every major nuclear engineering department operates or has access to a research reactor. These facilities serve important roles in the education of nuclear engineers. They are also vital as research facilities for many university departments other than nuclear, and play an important service role for industry.

As an example of the use of these facilities, at the University of Virginia we have many programs using our reactor. These include projects related to nuclear plant life extension; projects on studying corrosion in a radiation environment; measurement of trace materials in many substances; and many other projects of an advanced nature.

Our facility is also well-used by visitors under the reactor sharing program, a DOE program to support the availability of university reactors to regional schools without comparable facilities.

In Virginia we have had visitors from most of the colleges and universities in the state for tours, class experiments and student projects. The past two years we have hosted a week-long summer course for middle and high school teachers at our facility.

These programs illustrate the usefulness of these facilities as educational tools for a wide range of students. Most of the university reactor facilities were built in the late 1950's and early 1960's with AEC sponsorship. Since the early days, there has not been a Federal agency specifically funding research, equipment or upgrade costs for these facilities. The traditional support by the parent universities is in danger of eroding as States and universities are more and more reluctant to increase or even to maintain current support.

Several university reactors have recently shut down. Federal funds for reactor operations, facility improvements and research equipment associated with these reactors used to be inadequate, threatening the viability of the facilities. An annual fund of $3 million would be a start to revitalizing the university research reactor community.

In conclusion, we are grateful to Congress for support of nuclear engineering education and the $5 million fund that was allocated last year. We hope that that fund will be restored next year and increased.

Thank you.

[The prepared statement of Dr. Williamson follows:]

TESTIMONY

Before

Subcommittee on Energy Research and Development

House Committee on Science Space and Technology

in behalf of

Nuclear Engineering Department Heads Organization

American Society of Engineering Education

by

Dr. Thomas G. Williamson

Chairman, Department of Nuclear Engineering
and Engineering Physics
University of Virginia

March 17, 1988

Good morning Madam Chairman and Distinguished Members of the Committee. I am Professor Thomas Williamson, Chairman of the Department of Nuclear Engineering and Engineering Physics at the University of Virginia. I am also chairman of the Nuclear Engineering Department Heads Organization (NEDHO). NEDHO represents the nuclear engineering academic departments and programs in the country. This community consists of about 40 programs in 29 states. Twenty-six of these departments offer accredited degrees in nuclear engineering and include representation of the top engineering schools in the country.

We are grateful to the Congress for support of nuclear engineering education by appropriating five million dollars in the 1988 DOE budget for research and fellowships. We believe that these funds serve a real need and will be wisely administered in a timely fashion. Programs are in place to allocate these funds: approximately two million dollars for a new research initiative, one million dollars for continuation of research begun in previous years, three quarters of a million dollars for new fellowships, one quarter of a million dollars for support of university research reactors and smaller amounts for a National Academy study of the discipline of nuclear engineering and for national laboratory programs for university personnel.

I will briefly discuss the fellowship program, the new research initiative, and university research reactors.

FELLOWSHIPS

If nuclear power is to remain a viable energy option, a work force of nuclear energy professionals must be available. A vigorous program of support for graduate students, such as a fellowship program, will have a major beneficial effect on enrollments and on the supply of nuclear professionals. Enrollments in nuclear engineering graduate programs have decreased by 35% from a high of 2,079 students enrolled in 1975 to 1,355 enrolled in 1986. In the decade of the eighties the number of PhD'S awarded has decreased by 9% to 120 and the number of bachelor and master degrees each decreased by 17% to 1,344 undergraduate degrees and 806 Master's degrees. The percentage of PhD's awarded to foreign nationals in 1986 was 53%. The PhD production is particularly troubling since, as many of the foreign nationals return to their own countries, the number of PhD graduates available to United States employers, including the universities and the national laboratories is declining. The need of the universities is particularly troubling since 65 % of the faculties of the nuclear engineering departments are senior professors and only 14 % assistant professors. Many faculty members, like myself, started teaching in the late fifties and early sixties and are nearing the ends of their careers. The universities will soon be looking for bright young engineers to teach the next generation.

The Department of Energy and its predecessors have supported graduate fellowships in nuclear engineering and health physics with an active program that peaked with approximately 170 fellows in the early sixties. In 1976 this program was stopped. A nuclear engineering and health physics fellowship program, administered by Oak Ridge Associated Universities, was reinstated by the Office of Nuclear Energy in 1982. In the present academic year there are 20 fellows in the universities. With the funds appropriated by Congress in 1987, ten additional nuclear engineering and health physics fellowships will be started in 1988. I understand that there are 57 student applications for the fellowships to be awarded in 1988 and almost half of the applicants have grade point averages of 3.6 or greater. As a further indication of the quality of the applicants to this program, in 1986 there were 12 students named as honorable mention of which three were awarded fellowships. The average grade point of this honorable mention group was 3.72. This is a truly talented applicant pool and it is a shame that they can not all be funded.

In the four-year history of the present fellowship program there have been 35 graduates; 22 of these graduates are either employed by DOE or a DOE contractor and 4 are employed by universities. All but one of the graduates are working in an energy-related occupation. This indicates the direct benefit that DOE and the country is receiving through the fellowship program.

The fellowships are awarded in a national competition and the students are allowed to attend those universities with participating programs. The Nuclear Engineering Department Heads Organization recommends that a traineeship program be established. With a traineeship, which is granted to the university, the individual department will make the award. This process will provide additional flexibility in attracting students to the discipline.

The fellowship program has been successful in attracting good students to nuclear engineering and in providing manpower for DOE and the nuclear industry. The program should be further expanded to accommodate an additional 45 fellows and trainees each year at a cost of three million dollars.

RESEARCH

Research is an important component of the university educational activity for two reasons. Thesis research is a vital experience in the education of a young professional involving integration of classroom materials and the opportunity for creative expression. The universities through their research programs offer the nuclear power industry unparalleled access to an environment and population anxious to explore and generate new perspectives on significant and challenging problems, Secondly, through funded research opportunities students are able to finance a significant part of their education while simultaneously acquiring key elements of that education.

The 1988 research initiative is funde. at approximately two million dollars. This program is administered by DOE through the Idaho National Engineering Laboratory and is now in the process of accepting proposals. The research initiative will be broadly based to address a number of issues facing the nuclear industry such as real-time instrumentation which will apply innovative measurement technologies to nuclear reactors, modern approaches to reactor operations and control, advanced reactor concepts to improve power reactor performance, applied nuclear sciences including health physics and medical applications of radioisotopes, and a better understanding of materials in a radiation environments. These are exciting topics which are designed to keep the nuclear industry at the forefront of technology.

This new program will probably fund between ten and twenty research projects for two years. With approximately 30 major nuclear engineering departments, 300 faculty and 1300 graduate students, this limited program will only reach a few. From the phone calls I have received from my cohorts in academia, I am convinced that DOE will be overwhelmed with excellent proposals. We believe that the program should at least be tripled to six million dollars in the 1989 budget.

UNIVERSITY RESEARCH REACTORS

Every major nuclear engineering department operates or has access to a research reactor. These facilities serve important roles in the education of nuclear engineers, as research facilities for nuclear engineering departments as well as for many other university departments, and as important service facilities for industry.

As an example of the use of these facilities, at the University of Virginia we have many programs using our reactor. These include two projects related to nuclear plant life extension, i.e. radiation effects on electrical cable insulation and radiation measurements in the vicinity of a power reactor pressure vessel, a project to study corrosion in a radiation environment, projects to measure trace materials in many substances, including foods, and a project to develop advanced techniques for neutron radiography. Our facility is also well used by visitors under the Reactor Sharing Program, a DOE program to support the availability of university reactors to regional schools without comparable facilities. In Virginia we have had visitors from most of the colleges and universities in the state for tours, class experiments and student projects. For the past two years we have hosted a week-long summer course for middle and high school teachers at our facility. These programs illustrate the usefulness of these facilities as educational tools for a wide range of students.

Most of the university reactor facilities were built in the late fifties and early sixties with Atomic Energy Commission sponsorship. Since the early days there has not been a federal agency specifically funding research, equipment and improvement costs for these facilities. The traditional support by the parent universities is in danger of eroding. States and universities are more and more reluctant to increase or even to maintain current support and several university reactors have recently been shut down. Federal funds for reactor operations, facility upgrades and research equipment continue to be inadequate, threatening the viability of all research reactor facilities. An annual fund of three million dollars would be a start to revitalizing these facilities.

SUMMARY

The decline of nuclear energy education in the United States threatens the ability of the country to supply enough nuclear energy professionals. Without an adequate supply of such professionals, the nuclear industry will eventually find it impractical or impossible to maintain the option of using nuclear energy for power generation. Many federal agencies will be competing for a declining pool of engineers and scientists educated in nuclear technology.

If nuclear power is to remain a viable energy option, a work force of nuclear energy professionals, nuclear engineers and health physicists, must be available. These nuclear energy professionals are educated throughout the United States at universities offering nuclear engineering and science education programs. Less and less attention, however, is being focused on these programs. In a time of budget cuts, federal and state governments and even universities themselves are becoming reluctant to continue financing these nuclear energy education programs. Some educational experts speculate that, if the current trend continues, nuclear energy education programs will have difficulty gearing up to provide the necessary nuclear energy professionals for a resurgence of nuclear power and for the continuing needs of the national laboratories.

Universities need the vigorous support of the nuclear power industry and the federal government to enable them to continue to produce nuclear energy professionals. This vigorous support must be in the forms of fellowships, research support, laboratory equipment, and assistance for university reactors.

NUCLEAR ENGINEERING ACADEMIC DEPARTMENTS

FACT SHEET

MARCH 1988

NUMBER OF PROGRAMS:

42 PROGRAMS IN NUCLEAR ENGINEERING IN 29 STATES

12 PROGRAMS OF NUCLEAR ENGINEERING AS OPTIONS IN OTHER DISCIPLINES

26 NUCLEAR ENGINEERING PROGRAMS IN 23 STATES ACCREDITED BY THE ACCREDITING BOARD FOR ENGINEERING AND TECHNOLOGY (ABET)

FACULTY

309 FACULTY IN 33 PROGRAMS - AVERAGE 9.4 FACULTY PER PROGRAM

STUDENTS

ENROLLMENTS:	1986	RECENT PEAK	DECLINE IN EIGHTIES
PhD	549	606 (1982)	9.4%
MASTERS	806	951 (1983)	15.2
UNDERGRADUATE	1344	1701 (1983)	21.0

DEGREES	1986	RECENT PEAK	
PhD	120	132 (1984)	9.1%
MASTERS	283	342 (1982)	17.2
BACHELORS	572	692 (1981)	17.3

RESEARCH REACTORS

16 UNIVERSITIES OPERATE RESEARCH REACTORS AT POWER LEVELS 1.0 MW OR GREATER

15 UNIVERSITIES OPERATE RESEARCH REACTORS AT POWER LEVELS BETWEEN 1.0 KW AND 1.0 MW

FOUR UNIVERSITY REACTORS HAVE SHUT DOWN RECENTLY

Attachment to testimony
Subcommittee on Energy Research and Development
March 17, 1988
Dr. T. G. Williamson

Required funds for Nuclear Engineering education and research

FELLOWSHIPS AND TRAINEESHIPS:	
FELLOWSHIPS: Awarded on a national competition TRAINEESHIPS: Awarded by universities	
45 new fellows and trainees @ $22,000 each for 3 years	$ 3.0 M
RESEARCH:	
For 30 academic programs containing 300 faculty and 1300 graduate students	
40 research initiatives - 1 to 2 faculty and several graduate students each @ $100,000 - $250,000 each program	$ 6.0 M
REACTOR SUPPORT:	
30 facilities @ $100,000 each	$ 3.0 M
NATIONAL LABORATORY PROGRAMS:	
National laboratory pass-through programs to provide for academic research in direct support of laboratory programs	$ 2.0 M
TOTAL	$ 14.0 M

Mr. STALLINGS. Thank you, Professor Williamson.

The final witness, Professor Gonzalez, we welcome you and look forward to your testimony.

STATEMENT OF DR. RALPH C. GONZALEZ, DISTINGUISHED SERVICE PROFESSOR OF ELECTRICAL ENGINEERING, THE UNIVERSITY OF TENNESSEE, KNOXVILLE, TN

Mr. GONZALEZ. Good morning and thank you, Mr. Chairman.

My name is Ralph Gonzalez. I am Professor of Electrical Engineering, University of Tennessee, and I am testifying on behalf of the DOE nuclear engineering university program of robotics and advanced reactors.

I have submitted a lengthy statement, but for the sake of time I will cut this down to about five minutes. What I would like to do is give you an overall view of the program and its significance as to how it stands at this time.

The U.S. Department of Energy has provided support in fiscal years 1987 and 1988 to four universities in the Oak Ridge National Laboratory. In order to pursue research leading to the development and deployment of an advanced robotics system capable of performing tasks that are hazardous to humans in really significant occupational radiation exposures and whose execution times can be reduced if performed by automated systems.

The goal is to develop a generation of advanced robotic systems capable of performing surveillance, maintenance and repair tasks at nuclear energy facilities with spinoffs in other hazardous environments.

Now this research program is unique in the sense that it involves four universities directing the project. The universities involved are the University of Florida, the University of Michigan, the University of Tennessee, and the University of Texas.

The program is being coordinated by the Oak Ridge National Laboratory.

The key to this program is that it involves a very high level group of people consisting of about 12 professors and on the order of about 40 students. The research program is a one-term program with high technology implications and the pay-back of this program will accrue to the public, ratepayers, and the technology base for the country itself.

The health and safety aspects of being able to project an operator's capabilities without his presence are considerable. Need exists for modular, general purpose robotic devices that can, number one, reduce the routine occupational exposure to personnel during normal plant activities; two, provide for in-service inspection and surveillance; and three, to have the capability to deal effectively with radioactive leaks and spills thereby reducing personnel accident exposure levels; four, reduce the amount of radioactive waste material; five, decommission and replace major components.

An important part of this program is that it will also have a very significant role in the future of plant designs, such as the PRISM and SAFR programs discussed earlier in front of this Committee.

In the area of economic advantages, quantifiable economic benefits from the implementation of advanced robotics in nuclear power plants are related primarily to raising plant availability by executing testing and some maintenance tasks while the reactor is operating.

With purchased replacement power of a 1,000-megawatt plant, close to an average of $500,000 a day, it is estimated that loss of electrical production alone accounts for approximately $3 billion of replacement costs in this country every year.

Such areas as on-line monitor repairs of systems, on-line evaluation of our normal situation and so forth, the robotics program is expected to have a very significant impact.

The potential savings resulting from the availability of an intelligent maintenance robot being developed under this project are immense when applied to the potential economic consequences of an accident such as the TMI or Chernobyl accidents.

Cost: I will give you some figures that I think are interesting. The cost of cleanup and replacement power at TMI amounted to about $1 billion and $4 billion, respectively. Decommissioning the damaged Chernobyl reactor and on-site cleanup are estimated in excess of two billion dollars. We have estimated the savings from utilizing intelligent robot systems in these cases are estimated to be on the order of 25- to 40-percent savings. That ranges between $250 million and $800 million. It is interesting to note that the government of West Germany has an active robotics response program which they made available to the Soviets for cleanup purposes at Chernobyl. The robots failed within a very short period of time due to radiation damage in the reactor. This is one of many examples showing that R&D in the field of robotics for nuclear energy is in its infancy.

Robotics research is required for capabilities that go well beyond today's current commercial products. As we strive toward combined human/robot systems in which a human is used more in a supervisory capacity, and the robot autonomously carries out desired functions, major issues of a three-dimensional role modeling, seeing and understanding a multi-level sensor integration would be dealt with in real time, including supporting technologies of massively parallel computing and algorithm development. This type of work is generally best carried out in a university environment.

In addition to the advantages I have mentioned in the past few minutes, this program has a very significant impact in our educational system. In its present form, the program supports 12 professors, 10 graduate students, and over 30 graduate students at four major campuses across the country.

The program was funded at a level of $1.3 million in fiscal year 1987 and $2.7 million in fiscal year 1988. After the program was authorized by the House and the Senate last year, it was not reinstated into the DOE budget for the coming fiscal year.

We respectfully request that this Committee authorize the robotic program for fiscal year 1989 at a level of $3 million.

Thank you.

[The prepared statement of Dr. Gonzalez follows:]

TESTIMONY

Presented to

THE ENERGY RESEARCH & DEVELOPMENT SUBCOMMITTEE

by

Professor R.C. Gonzalez, University of Tennessee

on behalf of

THE DOE/NUCLEAR ENERGY UNIVERSITY PROGRAM IN ROBOTICS FOR ADVANCED REACTORS

March 17, 1988

The U.S. Department of Energy has provided support in Fiscal Years 1987 and 1988 to four universities and the Oak Ridge National Laboratory (ORNL) in order to pursue research leading to the development and deployment of an advanced robotic system capable of performing tasks that are hazardous to humans, that generate significant occupational radiation exposures, and/or whose execution times can be reduced if performed by an automated system. The goal is to develop a generation of advanced robotic systems capable of performing surveillance, maintenance, and repair tasks in nuclear energy facilities and in other hazardous environments.

The Universities of Florida, Michigan, Tennessee, and Texas; Oak Ridge National Laboratory; and their industrial partners, Combustion Engineering, Martin Marietta Baltimore Aerospace, Odetics, Remotec, and Telerobotics International, are working as one team. ORNL coordinates the teamwork.

The strategy adopted in order to achieve the program goals in an efficient and timely manner consists in utilizing, and advancing where required, state-of-the-art robotics technology through close interaction between the universities and the manufacturers and operators of nuclear power plants. The approach to achieving the program objective is a transition *from teleoperation to the capability of autonomous operation* within three successive generations of robotic systems. The robotic system will always have the capability to request human assistance.

Progress of work by the team members towards the common goal will be demonstrated during the project through coordinated experiments. For these experiments, equipment and software developed at the different institutions will be assembled in order to test the planned interaction between components and to perform tasks of increasing complexity as the project progresses. ORNL will coordinate these demonstrations.

The motives for undertaking a comprehensive research effort in the application of advanced robotics to maintenance, inspection, repair and testing tasks in hazardous environments reflect both monetary considerations and health and safety concerns. The development of a general-purpose robot to perform skilled labor tasks in restricted environments can have extensive payback in areas of energy systems (nuclear and fossil units) and other hazardous activities.

Nuclear energy applications are obvious because of the hazardous environment generated by the presence of radiation. With thousands of sophisticated subsystems and safety-related hardware, nuclear power plants require hundreds of trained personnel working around the clock to service and maintain numerous mechanical devices. Annually, hundreds of thousands of hours of maintenance are required to continue operating the plant as well as to comply with stringent safety regulations which mandate the routine inspection and monitoring of critical plant components and safety systems. Much of the inspection and maintenance of nuclear power plants requires that the plant itself be out of service or drastically reduced in power output in order to lower radiation levels to levels where humans can work safely.

The health and safety aspect of being able to project man's capabilities without his presence are considerable. In summary, electric utility companies show a need for modular, general-purpose robotic devices that can: (1) Reduce the routine occupational exposure of personnel during normal plant activities like inspection, surveillance, maintenance, and radioactive waste handling. (2) Provide for in-service inspection, surveillance, and on-line maintenance which will reduce plant downtime and save costly replacement power. (3) Have the capability to deal effectively with radioactive leaks or spills, thereby reducing personnel accident exposure levels. (4) Reduce the amount of radioactive waste material and expendables associated with maintenance activities. (5) Decommission and replace major components.

The additional safety aspect resulting from the ability to undertake activities that might otherwise not be possible is less obvious but just as real. An automated repair system will not only preserve the health and safety of the personnel directly involved but also may correct a situation which, if allowed to continue, could have farther-reaching health and safety consequences.

In the area of economic advantages, quantifiable economic benefits from the implementation of advance robotics technology for nuclear power plants are related primarily to raising plant availability by executing testing and some maintenance tasks while the reactor is operating. With purchase replacement power for a 1000 MWe plant costing an average of $500,000 a day, it is estimated that lost electrical production alone accounts for approximately $3 billion of replacement costs in the U.S. Nuclear industry. In such areas as on-line monitored repair of systems, on-line evaluation of abnormal situations, early preparations for refueling and maintenance outages undertaken simultaneously with bringing the plant to a shutdown condition, advanced robots will save considerable downtime that is currently required until human personnel can enter the workplace. A boiling water reactor, for example, has to be shut down for 1 to 2 days until the temperature in the drywell reaches a level that allows personnel to enter that workplace. Robots can enter this area during plant operation or immediately after plant shutdown.

For a range of individually identified maintenance and health physics tasks, a recent EPRI study estimated costs ranging from $100,000 to $1,000,000 each. The study also cited the limited availability of robotic equipment suitable for the nuclear industry. Studies by the Public Service Electric and Gas Company have predicted annualized robot savings for several of these tasks ranging from $47,000 to $100,000.

In 1985 and 1986, nuclear plants, on the average, accounted for exposures of 700 man-rem per unit per year for boiling water reactors and 400 man-rem per unit per year for pressurized water reactors. These values are considered "as low as reasonably achievable" (ALARA) until new technology like intelligent robots is implemented. With personnel exposure costs often exceeding $5,000 per man-rem in U.S. power plants, these exposure levels would yield potential cost savings of several million dollars per year per plant with implementation of robots.

The potential savings resulting from the availability of an intelligent maintenance robot being developed under this project are immense when applied to the potential economic consequences of an accident event such as TMI-II or Chernobyl. The costs for clean-up and replacement power at TMI-II amounted to $1 billion and $4 billion respectively. Entombing of the damaged Chernobyl reactor and site clean-up are estimated at $2 billion. There are no estimates for off-site costs. The savings from utilizing intelligent robots in these situations are estimated at 25% to 40%, or $250 million to $800 million for the clean-up alone.

Advanced robotics also should be developed to handle various high exposure and/or potential high risk activities associated with plant life extension. The current schedule for implementation of advanced robots matches the tentative schedules of many utilities for major plant life extension activities.

Additional savings can also be expected from the higher quality of work achieved by the automated process and the elimination of the low productivity of maintenance personnel who must toil under arduous operating conditions with protective clothing and life support systems which restrict capability and create tired workers precluding continuous output of high-quality work.

Applications of advanced robots in the nuclear power industry are obvious because of the hazardous environment generated by the presence of radiation and excessive heat. Similarly, space activities due to their hostile environments of radiation, vacuum, and extremes of heat and cold are prime candidates for automated activities. Other areas, such as firefighting, underwater drilling, mining and repair activities, can also be expected to make extensive and productive use of general purpose, intelligent maintenance robots. In summary, the total economic benefit of the automated robot system developed under this project in the 1990's can be expected to exceed many billions of dollars per year with substantial long-term benefits.

The program was funded at a level of $1.35M in FY'87, $2.7M in FY'88, and is zeroed-out for FY'89. The four universities and ORNL are actively pursuing support to reinstate the funding level at $3.0M for FY'89.

PANEL 3: DISCUSSION

Mr. **Stallings**. Thank you, Professor Gonzalez.

Gentlemen, let me pose this question and any one of you who would like to respond, I would appreciate it. The Department of Energy has chosen to submit a budget which ignores the Congressional directive to support the engineering departments directly through grant funding within the Office of Energy Research Programs.

Have any of you had an opportunity to discuss this problem with the Department and, if so, what has been their response?

Dr. **Williamson**. I think we did not expect it to be in this budget. We hope, of course, it will be in the next budget and we had hoped to come to Congress to have it added to this budget and then it would come in as a line item from the DOE budget in the 1990 budget. This was our expectation. I hope you will help us and put it in for the 1989 budget and then I am through.

Mr. **Stallings**. But you have not heard any comments or statements from them as to the appropriateness of this program, whether it was inadequate or was not working?

Dr. **Williamson**. No, sir, we have not.

Dr. **Gonzales**. Mr. Chairman, with respect to the robotics program, the program was started two years ago by Deputy Assistant Secretary Lyle Wilcox. He has since left his job and from a technical standpoint, we have received very high remarks from the DOE people involved in the program. The lack of support appears to be at higher levels. However, we are hopeful that after the program continues this coming year, the higher level individuals will be convinced that it is a worthwhile effort.

Mr. **Stallings**. Thank you, Professor. Mr. Morrison.

Mr. **Morrison**. Thank you, Mr. Chairman. I am sorry we are pressed for time because I would like to explore with these gentlemen something that I think that we have all seen and that is a conflict between research dollars going to National Laboratories as opposed to a base university system and I am not so sure what the best policy is. It is high time we re-visited that.

I take it from all of your testimonies that you are relying on bake sales to maintain your research programs and their continuity just doesn't cut it in this day and age so I guess it is not so much a question as just an appreciation for your being here and the work that your schools are providing.

I am thoroughly convinced that this sort of lull in interest in nuclear power that unless we provide more programs through you we are not going to have the trained engineers ready to take over the needs of tomorrow particularly as we look at potential new orders just absolutely essential for power production as we head into the middle 1990's.

So you have struck a responsive chord. Let's hope, Mr. Chairman, we can find some money.

Dr. **Williamson**. May I just comment on the "bake sale" in our department. About half of our funding comes from industry and about half from the Federal Government and the industry is typically up to the $20,000 or $30,000 level and we have to work awfully hard to get that. You are right, bake sales are just about right.

Mr. MORRISON. I would rather you were spending your time in the classroom and with those students than having to go out making contacts to keep your programs alive. Something is wrong with our priorities when that has to happen. Thank you.

Mr. STALLINGS. Yes, I certainly agree with Mr. Morrison. I think there is a great deal of support on this committee for the kinds of things that you gentlemen are doing and we will do what we can to continue that. We do appreciate the testimony from the three of you. This concludes the Subcommittee hearings for the week.

[Questions and answers for Panel 3 follow:]

PENNSTATE

(814) 865-1341

College of Engineering
Nuclear Engineering Department

231 Sackett Building
The Pennsylvania State University
University Park, PA 16802

April 22, 1988

Marilyn Lloyd, Chairman
Subcommittee on Energy Research
  and Development
U.S. House of Representatives
Committee on Science, Space,
  and Technology
B-374 Rayburn House Office Building
Washington, DC 20515

Dear Chairman Lloyd:

Enclosed is my response to your letter of April 5, 1988 requesting supplemental information for the record of the hearing on March 17, 1988.

If there are any questions on the enclosed material, or you need further information, please don't hesitate to contact me.

Sincerely,

Edward H Klevans

Edward H. Klevans
Professor and Department Head

EHK/tsn
Enclosure

An Equal Opportunity University

Response to the SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
Questions for the Record for the Hearing of March 17, 1988
Professor Edward H. Klevans
The Pennsylvania State University

1. To what extent do your university programs directly contribute to the mainstream activities of the Department of Energy's programs in nuclear energy R & D?

The Nuclear Engineering Department at Penn State currently has two programs funded by the Department of Energy. The first of these is entitled "A Light Water Ultra-Safe Plant Concept." The Office of Nuclear Energy, in conjunction with the Electric Power Research Institute (EPRI), is funding industry studies of several advanced light water reactor designs with enhanced safety features. Our funding comes from a university-designated program which is separate from the industry projects, but our work is contributing to the development of concepts which can hopefully lead to LWR's that have sufficient safety to be acceptable to the public. Several novel ideas have been introduced into our design that may be suitable for industry use. For example, to cover loss-of-offsite power (blackout), we have introduced a small turbine-generator system on the secondary side of the plant to provide backup power for critical pumps. We are also developing an advanced control strategy. These efforts will contribute to mainstream activities of DOE.

We have been promoting our work by making presentations at American Nuclear Society meetings, at EPRI meetings, and through meetings with personnel at Westinghouse (to the group working on the Westinghouse Advanced AP 600 design). Westinghouse has found our system modeling work to be sufficiently interesting that they are developing a research project for us to assist them in improving one of their computer models. (This points out how DOE funding can lead to university-industry interaction and research. Without the expertise we developed from the DOE project we would not have been in a position to work with Westinghouse.)

Our second project is funded by the Liquid Metals Research pass-through program for university research on LMR projects. We are being funded to test and install an expert system on the EBR-II argon cooling system. This is a cooling system which is used when fuel elements are removed from the reactor and transferred to the spent fuel storage building. This project is clearly in direct support of a mainline DOE nuclear energy R&D program.

2. Could you give this Committee some indication on the status of nuclear engineering education in this country. For example, over the last several years, we understand that several nuclear engineering departments have either closed or been folded into other engineering departments. Could you give us some statistics on this, and what the impact has been on nuclear engineering education in this country?

In regard to nuclear engineering departments closing or merging with other departments, my colleague Professor Thomas Williamson has compiled data on this topic and he will provide this information in his response to your question. I will defer to Professor Williamson on this topic.

I would like to comment on enrollment and degree data, however. Data for the past five years is shown on the enclosed table. The data indicate that undergraduate enrollment at the junior and senior level has dropped for the fifth straight year. The number of B.S. graduates last year was at a fifteen year low, with a drop of 11% compared to the previous year. M.S. enrollment also fell for the fifth straight year and is now at a fifteen year low. Ph.D. enrollment showed a 12% increase last year, but a 19% drop in the number of degrees. To maintain doctoral enrollment there has been a gradual increase in the percentage of foreign nationals. For 1987 the percentage of degrees granted to foreign nationals increased from 53% to 58%. The decreasing enrollment will undoubtedly lead to pressures to close or merge additional departments over the next several years.

> Could you give us funding support levels per student in your department and breakdowns between federal and private support?

In Fall 1987 there were 40 graduate students in Penn State's Nuclear Engineering Department. Our research funding for 1986/87 was $620,000, indicating $15,550 per student. Actually, stipend and tuition is approximately $20,000 per student, so it is important to understand that only 23 of the students were funded on research grants and contracts. The remainder were either teaching assistants (5), fellowship students (4), or were supported by their government, a company, or the IAEA (8). Including research costs, a value of $26,000 per student is approximately correct.

Regarding the $620,000 in research funding, $270,000 was from federal support (DOE, NRC, NSF, NRL, Dept. Navy) and $350,000 was from private support. Private support was received in two ways. We have an affiliates program with ten members each providing $15,000 per year. Second, a group of utilities is providing funding for low level radioactive waste research. Finally, we have funded projects from two utilities, IBM, Chrysler Corporation, and Monsanto-Mound.

In response to Republican Member Questions for the Record:

1. The national laboratory pass-through program seems to be a mutually beneficial program to both the laboratory and the university. What is the scope now, and how should it be expanded?

In FY 1986 the program was funded at $1,315,000; in FY 1987 at $1,465,000; and in FY 1988 at $1,130,000. The request for FY 1989 is zero. It appears that this worthwhile program is being phased out.

The pass-through program is currently budgeted and administered by the Reactor Systems Development and Technology Office. The scope has been of narrow focus: to provide research support to faculty and students to assist the contractors who receive Liquid Metal Reactor (LMR) funds. Most of the grants have tended to be rather small and short term, i.e., they have supported near-term problems with enough funds for one graduate student for his or her M.S. thesis research. The funding has frequently been too small and short term to support Ph.D. research. In spite of these limitations, it has played a valuable role in keeping universities involved in the LMR programs.

In my view, sufficient funds should exist so that concepts besides the LMR can be studied. For example, contractor support for advanced LWR concepts which receive DOE funds, or support for modular gas cooled reactors should also be possible. In addition, grants should be sufficiently large (greater than $35,000) so that faculty are encouraged to participate in the program. A support level of $2,000,000 is appropriate at this time to accomplish these goals. The program should be administered by the Office of Nuclear Energy of DOE. It should be recognized that such a program is valuable, but is not a substitute for a University base technology program which handles projects of large scope and longer term funding.

2. What are the employment opportunities for nuclear engineering graduates? Have you pursued industry-sponsored research projects for assistantships?

At this time the employment opportunities are reasonably good, although the students have to be more aggressive to find jobs than they have in past years. The current job market is national in nature, rather than being heavily regional, as in the past. This past year our students have taken jobs with six utilities, the NRC,. three architect/engineering firms, the Navy Shipyard, GE, and a national laboratory. Job announcements have been received from many companies and students are taking interview trips.

Some of the utilities are now doing much of their hiring by using co-op education programs. Pennsylvania Power and Light Company, for example, has informed me that they plan to give preferential treatment in hiring to such students. Eleven of our juniors and seniors were on the co-op program this year at four different utilities and the NRC.

Regarding industry-sponsored research projects, Penn State has been reasonably successful. First, we established an industry affiliates program in 1985 with an annual fee of $15,000 per year. Ten companies belong to this program. It is supporting approximately six research projects including six graduates per year. (Faculty effort is being subsidized by the University.) In addition to this program we have three research projects supported by Pennsylvania Power and Light Company, one by General Public Utilities, one by Monsanto-Mound Laboratories, and one by IBM. We are currently negotiating additional projects with EPRI and with two other companies.

Industry support has been extremely important to our department. However, the utilities are vigorously pursuing cost containment and research is one area being cut. One of our projects was a casualty this year. The net effect is that nuclear industry support may be more difficult to obtain in years to come.

Finally, it should be pointed out that industry research generally is applied and there is little opportunity for basic, long term research. Thus the industry support supplements but cannot replace a federal nuclear energy research program for universities.

TABLE 1

DOE's Annual Survey of Nuclear Engineering Departments

Year	Jr & Sr Enrollment	MS Enrollment	PhD Enrollment	BS Degrees	MS Degrees	PhD Degrees
1983	1701	951	564	654	325	124
1984	1643	924	559	660	316	132
1985	1500	835	582	612	306	113
1986	1344	806	549	572	283	120
1987	1307	793	613	509	295	97

UNIVERSITY OF VIRGINIA
DEPARTMENT OF NUCLEAR ENGINEERING AND ENGINEERING PHYSICS
NUCLEAR REACTOR FACILITY
SCHOOL OF ENGINEERING AND APPLIED SCIENCE
CHARLOTTESVILLE, VA 22901
April 15, 1988

Telephone: 804-924-7136

Ms. Lottie McCaw-Daniels
Subcommittee on Energy Research and Development
B-374 Rayburn House Office Building
Washington, DC 20515

Dear Ms. McCaw-Daniels

On March 17 I testified before the Subcommittee on Energy Research and Development on behalf of the nuclear engineering education community. Enclosed are responses to questions asked by the chairman.

I appreciate the opportunity to present this testimony and the interest of the committee in these important matters.

Yours truly,

TGWilliamson

T.G. Williamson, Chairman
Nuclear Engineering Department
Heads Organization
and
Chairman, Department of Nuclear
Engineering and Engineering
Physics

Enclosures

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

Hearing on DOE FY 1989 Authorization for Nuclear Fission
March 17, 1988

Professor Thomas G. Williamson, Chairman
Department Of Nuclear Engineering and Engineering Physics
University of VIrginia

1. To what extent do your university programs directly contribute to the mainstream activities of the Department Of Energy's programs in nuclear energy R&D?

The Nuclear Engineering Department at the University of Virginia directly contributes to the activities of the DOE nuclear energy programs in two ways 1) research and 2) supplying PhD graduates for the national laboratories.

Research: The following active research programs are related to the DOE nuclear energy mission:

a) Reactor Life Extension - Radiation effects on cable insulation - industrial sponsorship

b) Reactor Life Extension - Pressure vessel dosimetry - industrial sponsorship

c) Reactor thermal-hydraulics - flow in narrow channels - transient analysis - DOE and industrial sponsorship

d) Radiation Enhanced Corrosion - application to waste management - industrial sponsorship.

In the past we have had active programs in the safety of liquid metal reactors and in reactor source term analysis.

PhD Graduates - This department has graduated 67 PhD's in nuclear engineering and approximately one third have worked for a national laboratory or a government contractor.

2. Could you give this Committee some indication on the status of nuclear engineering education in this country. For example, over the last several years, we understand that several nuclear engineering departments have either closed or been folded into other engineering departments.

-- Could you give us some statistics on this, and what the impact has been on nuclear engineering education in this country?

One indication of the number of nuclear engineering programs is the fact that there are 26 programs accredited by the Accrediting Board for Engineering and Technology (ABET) in 23 states.

Data on nuclear engineering enrollments and programs taken from "Nuclear Engineering Enrollments and Degrees - 1986", DOE/ER-0323.

Nuclear Engineering Programs
  42 programs in 29 states
of these
  26 offer both undergraduate and graduate degrees
  2 offer only undergraduate degrees
  14 offer only graduate degrees
In the following programs some schools are listed several times
Nuclear option in Chemical Engineering
  10 programs in 8 states
Nuclear option in Electrical Engineering
  10 programs in 7 states
Nuclear option in Mechanical Engineering
  18 programs in 14 states

There are 14 programs listed as having suspended programs of which 10 of have been suspended since 1980. These suspended programs include

Tuskegee Institute
San Jose State Univ.
Catholic University
Univ. of Pennsylvania
Memphis State Univ.
Stanford University
Colorado State University
University of Nebraska
State Univ of N.Y. Buffalo
Polytechnic Inst. of New York

In addition, I am aware of programs at Northwestern University, Virginia Polytechnic Institute, and at Georgia Tech which have combined nuclear engineering into other programs.

University research reactors at UCLA, UC Berkeley, UC Santa Barbara and at VPISU have closed in the past several years and the faculty of the University of Washington have recommended the shutdown of their reactor.

The following chart summarizes enrollments and degrees awarded in nuclear engineering:

ENROLLMENTS:	1986-87	PEAK	DECLINE
PhD	613	665 (1975)	8 %
MASTERS	793	1414 (1975)	44
UNDERGRADUATE	1307	2121 (1977)	38

DEGREES	1986-87	PEAK	
PhD	97	146 (1976)	33 %
MASTERS	295	554 (1977)	47
BACHELORS	509	863 (1978)	41

Another statistic of interest is the fact that of the 307 faculty of nuclear engineering 65 % are senior professors, 21 % associate professors and 14 % assistant professors. (Nuclear Engineering Faculty Handbook, American Nuclear Society, 1987) This indicates a need for young faculty.

-- Could you give us funding support levels per student in your department and breakdowns between federal and private support?

In 1987 the Department of Nuclear Engineering and Engineering Physics had sponsored research as follows:

Total	$ 1,193,000	
Faculty	14	
Graduate students	45	full time
Average	$ 85,000	per faculty
	$26,000	per graduate student
Division by source		
Federal	51%	
Industrial	56%	
Foundations	3%	

The department is evenly split between nuclear engineering and engineering physics.

T G Williamson

T.G. Williamson, Chairman
Nuclear Engineering Department
Heads Organization
and
Chairman, Department of Nuclear
Engineering and Engineering Physics

THE UNIVERSITY OF TENNESSEE
KNOXVILLE

College of Engineering

Electrical and Computer Engineering

April 19, 1988

The Honorable Marilyn Lloyd, Chairman
Subcommittee on Energy Research and Development
U.S. House of Representatives
Suite 2321 Rayburn House Office Bldg.
Washington, DC 20515

Dear Mrs. Lloyd:

This is in response to the three questions you asked in your letter of April 5.

Question 1. Have there been cooperative efforts between universities and the private sector in the development of robotics for nuclear power plant applications? Does industry provide any funding to universities to support such activities?

Answer. To my knowledge, this is the first program in robotics for nuclear reactors involving a team of universities, a national laboratory, and the private sector. The type of work in this program is long-term, high-risk research. Due to these factors, and also due to the fact that the program is in its infancy, has caused industry to take a "wait and see" attitude at this point as far as funding goes. However, we expect that as the program matures and new technology is generated, we will be able to supplement the budget with industrial support for specific applications.

Question 2. Have any nuclear power plants in this country implemented robotics as part of their operation? In this regard, how do we compare with Europe and Japan?

Answer. There have been applications of manual robots (typically called teleoperated systems) at places like Three-Mile-Island, Wisconsin Power & Light, and Nine-Mile-Island (run by Niagara Power & Light). The research we are doing is focused on autonomous robots that will require little human supervision. The advantages of this approach are many, including faster response, more complete coverage for routine inspections, and performance of tasks in a plant that would be difficult, if not impossible, to achieve by remote operation.

The U.S. is behind both Europe and Japan in this type of technology. For instance, the Japanese budget for robotics for nuclear power in their FY'88 is $9M U.S. dollars (Source: Annual Report to DOE, Enclosure 10, Overview of FY'88 Japanese budget).

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The French have an active robotics program in connection with their Breeder Reactor. In Germany, the Nuclear Research Center in Karlsruhe has committed to switching 60% of their budget into robotics activities in the next five years.

Question 3. What level of funding has your Consortia received in FY 1988 to support your work in robotics, and what do you estimate your need to be in FY 1989?

Answer. We received $2.7M in FY'88 and have requested $3.0M for FY'89.

Thank you for taking the time to ask for these additional details. Please let me know if you need any further information.

With best regards,

Ralph Gonzalez

R.C. Gonzalez
Distinguished Service Professor

/mmb

Mr. STALLING. Our next meeting on the DOE budget will be a full Committee hearing on the Superconducting Super Collider beginning at 1:00 p.m. next Tuesday, March 22, 1988 in our other hearing room down the hall, that is Room 2318.

Gentlemen and Professor Williamson, I think your students would be pleased with your efforts. In fact, Mr. Morrison and I would be happy to meet them for a moment afterwards if you would like. With that, this hearing is adjourned.

[Whereupon, at 11:55 a.m., the Subcommittee was adjourned to reconvene at the call of the Chair.]

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